AUGUST 1960

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AMERICAN WATER WORKS ASSOCIATION

In this issue:

NATIONAL WATER RESOURCES
Hollis, Schad

FLORIDA RESOURCES AND CONSERVATION
Wakefield

WASTE DISPOSAL AND WATER QUALITY
Rorabaugh

RESEARCH IN DESALINIZATION
Cywin, Finch, Grune, Zandi

MAIN EXTENSION AT DALLAS
Graeser

PUBLIC SUPPORT FOR BONDS
Sowden, Millar

EQUIPMENT FOR MACHINE BILLING
Tompkins, Copley

TASTE AND ODOR FROM RESERVOIRS
Allen

CORROSION OF COPPER TUBING
Task Group Report

EXPERIENCE WITH MAIN BREAKS
Arnold, Clark, Remus, Niemeyer

WATER CIRCULATION AT HAMMOND
Larson, Guillou, Henley, Gent

NEW EDITION OF 'STANDARD METHODS'

Taste & Odor Peak where wherewithal of impalatability dwarfs Cascade Mountains in clearing for Seattle's Tolt Reservoir

Journal

AMERICAN WATER WORKS ASSOCIATION

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August 1960

Vol. 52 • No. 8

Contents

Pollution and National Water Resources........................Mark D. Hollis 959
Reprints Available.. 964
Activities of the Senate Select Committee on National Water Resources
Theodore M. Schad 965
Coagulant Aids for Potable-Water Treatment............................... 969
Water Resources and Conservation in Florida................John W. Wakefield 970
Problems of Waste Disposal and Ground Water Quality...Matthew L. Rorabaugh 979
Federal Research and Development Program for Saline-Water Conversion
Allen Cywin & Lewis S. Finch 983
Improved Solar Still Process for Desalting Sea and Brackish Waters
Werner N. Grune & Iraj Zandi 993
Main Extension Policies at Dallas............................Henry J. Graeser 1006
Winning Public Support for Bond Issues
Fergus Falls..Howard J. Sowden 1015
Denver..Robert S. Millar 1018
Selection of Equipment for Machine Billing Operations—*Joint Discussion*
Richard D. Tompkins & John G. Copley 1021
Taste and Odor Problems in New Reservoirs in Wooded Areas....E. Jerry Allen 1027
Cold-Water Corrosion of Copper Tubing.....................Task Group Report 1033
Experience With Main Breaks in Four Large Cities
Philadelphia...Gerald E. Arnold 1041
New York...Edward J. Clark 1045
Detroit...Gerald J. Remus 1048
Indianapolis...Howard W. Niemeyer 1051
Circulation of Water in the Hammond Distribution System
Thurston E. Larson, John C. Guillou & Laurel M. Henley 1059
Discussion...Abel H. Gent 1070
Annual Report of Joint Committee on Uniformity of Methods of Water Examination 1072
Preview of the Eleventh Edition of *Standard Methods*........................ 1074
Notes and Comment:
History of *Standard Methods*..................................Harry E. Jordan 1079
Questions and Answers on Biologic Infestations..............Task Group 2670 P 1081

Departments

Officers and Directors............ *2 P&R*
Coming Meetings................ *6 P&R*
Percolation and Runoff........... *37 P&R*
Correspondence.................. *54 P&R*
Condensation..................... *64 P&R*
Employment Information......... *88 P&R*

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LIST OF ADVERTISERS

Advertiser	P&R PAGE
Alabama Pipe Co.	—
Allied Chemical Corp., General Chemical Div.	45
Allied Chemical Corp., Plastics & Coal Chemicals Div.	21
Allis-Chalmers Mfg. Co.	—
Allis-Chalmers Mfg. Co., Hydraulic Div.	91
American Agricultural Chemical Co.	84
American Brass Co., The	27
American Cast Iron Pipe Co.	73
American Concrete Pressure Pipe Assn.	30, 31
American Cyanamid Co., Process Chemicals Dept	26
American Hard Rubber Co.	—
American Pipe & Construction Co.	33
American Well Works	—
Andrich Water Specialty Co.	—
Anthracite Equipment Corp.	70
Aqua Survey & Instrument Co.	—
Armco Drainage & Metal Products, Inc.	85
Badger Meter Mfg. Co.	—
Bailey Meter Co.	55
Bethlehem Steel Co.	89
B-I-F Industries, Inc.	5
Birdwell Div., Seismograph Service Corp.	—
Buffalo Meter Co.	53
Calgon Co.	—
Calmet Meter Div., Worthington Corp.	47
Carborundum Co., The	—
Carus Chemical Co.	—
Cast Iron Pipe Research Assn., The	68, 69
Centriline Corp.	—
Chain Belt Co.	20
Chapman Valve Mfg. Co.	—
Charles Machine Works, Inc.	41
Chicago Bridge & Iron Co.	65
Clow, James B., & Sons	7
Cochrane Corp.	—
Combination Pump Valve Co.	—
Darley, W. S., & Co.	70
Darling Valve & Mfg. Co.	49
De Laval Steam Turbine Co.	—
DeZurik Corp.	—
Dicalite Div.	—
Dorr-Oliver Inc.	Cover 3
Dresser Mfg. Div.	95
Eddy Valve Co.	7
Eimco Corp., The	82, 83
Electro Rust-Proofing Corp.	67
Ellis & Ford Mfg. Co.	—
Emhart Mfg. Co., Maxim Div.	—
Fairbanks, Morse	23
Fairchild Aerial Surveys, Inc.	—
Fiese & Firstenberger	9
Filtration Equipment Corp.	—
Fischer & Porter Co.	29
Flintkote Co., The, Orangeburg Div.	—
Ford Meter Box Co., The	22
Foxboro Co.	—
Gamon Meter Div., Worthington Corp.	14
General Chemical Div., Allied Chemical Corp.	45
General Filter Co.	77
Glenfield & Kennedy	—
Golden-Anderson Valve Specialty Co.	—
Graver Tank & Mfg. Co.	11
Graver Water Conditioning Co.	—
Greenberg's, M., Sons	—
Griffin Wheel Co.	—
Hagan Chemicals & Controls, Inc.	—
Halliburton Co.	—
Harco Corp.	—
Hays Mfg. Co.	46
Hersey-Sparling Meter Co.	28
Hungerford & Terry, Inc.	74
Ideal Electric & Mfg. Co.	—
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.	35
Inertol Co., Inc.	—
Infilco Inc.	—
International Salt Co., Inc.	10
Iowa Valve Co.	7
Johns-Manville Corp.	Cover 4
Jones Chemicals, Inc.	—
Keasbey & Mattison Co.	—
Kennedy Valve Mfg. Co., The	63
Klett Mfg. Co.	80
Koppers Co., Inc.	93
LaMotte Chemical Products Co.	—
Layne & Bowler, Inc.	81
Leopold, F. B., Co.	43
Lock Joint Pipe Co.	3
M & H Valve & Fittings Co.	12
Marathon Electric Mfg. Corp.	—
Monterey Sand Co.	—
Morgan Steel Products, Inc.	—
Mueller Co.	25
Multi-Metal Wire Cloth Co., Inc.	—
Nalco Chemical Co.	—
National Tank Maintenance Corp.	52
National Water Main Cleaning Co.	97
Neptune Meter Co.	36
Northern Gravel Co.	86
Olin Mathieson Chemical Corp.	13
Orangeburg Mfg. Co., Div. of The Flintkote Co.	—
Ozark-Mahoning Co.	—
Peerless Pump Div.	75
Pelton Div., Baldwin-Lima-Hamilton	39
Permutit Co.	—
Philadelphia Quartz Co.	90
Photovolt Corp.	15
Pilot Mfg. Co.	78
Pittsburgh-Des Moines Steel Co.	—
Pittsburgh Equitable Meter Div. (Rockwell Mfg. Co.)	98
Plastics & Coal Chemicals Div., Allied Chemical Corp.	21
Pollard, Jos. G., Co., Inc.	18
Portland Cement Assn.	—
Pratt, Henry, Co.	—
Precision Chemical Pump Corp.	—
Preload Co., Inc.	—
Pulsation Controls Corp.	52
Reilly Tar & Chemical Corp.	24
Roberts Filter Mfg. Co.	—
Rockwell Mfg. Co.	98
Rohm & Haas Co.	71
Ronald Press Co.	—
Ross Valve Mfg. Co.	—
Shell Chemical Corp.	—
Simplex Valve & Meter Co.	19
Smith, A. P., Mfg. Co., The	87
Southern Pipe Div. of U.S. Industries	50, 51
Steel Plate Fabricators Assn.	79
Stuart Corp.	—
Tennessee Corp.	—
Trinity Valley Iron & Steel Co.	32
U.S. Pipe & Foundry Co.	16, 17
Vulcan Materials Co.	—
Wachs, E. H., Co.	—
Walker Process Equipment, Inc.	—
Wallace & Tiernan Inc.	34
Wheeler Mfg. Corp.	54
Wheeler, C. H., Mfg. Co.	—
Wiley, John, & Sons, Inc.	—
Wood, R. D., Co.	Cover 2
Woodward Iron Co.	—
Worthington Corp.	—

Directory of Professional Services—pp. *56-62 P&R*

Coming Meetings

AWWA SECTIONS

Sep. 7–9—South Dakota Section, at Grand Hotel, Watertown. Secretary, J. Darrell Bakken, Div. of San. Eng., State Dept. of Health, Pierre.

Sep. 12–14—Kentucky-Tennessee Section, at Andrew Johnson Hotel, Knoxville, Tenn. Secretary, Harold F. Mount, Gen. Mgr., Preston Street Road Water Dist. No. 1, 5400 Preston Hwy., Louisville, Ky.

Sep. 14–16—Virginia Section, at Cavalier Hotel, Virginia Beach. Secretary, Edward H. Ruehl, R. Stuart Royer & Assoc., 15 W. Cary St., Richmond.

Sep. 14–16—New York Section, at Saranac Inn., Upper Saranac Lake. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 22-22 Jackson Ave., Long Island City 1.

Sep. 21–23—Michigan Section, at Park Place Hotel, Traverse City. Secretary, T. L. Vander Velde, Chief, Section of Water Supply, State Dept. of Health, DeWitt Rd., Lansing.

Sep. 21–23—North Central Section, at Lowry Hotel, St. Paul, Minn. Secretary, Carl A. Flack, Registrar, Water Dept., 216 City Hall, St. Paul, Minn.

Sep. 25–27—Missouri Section, at Governor Hotel, Jefferson City. Secretary, Warren A. Kramer, Chief, Water Supply, Div. of Health, State Office Bldg., Jefferson City.

Sep. 28–30—Wisconsin Section, at Loraine Hotel, Madison. Secretary, Harry Breimeister, Bureau of Engineers, 607 Municipal Bldg., Milwaukee.

Sep. 28–30—Canadian Section, Maritime Branch, at Charlottetown Hotel, Charlottetown, P.E.I. Secretary, J. D. Kline, Gen. Mgr., Public Service Com., Halifax, N.S.

Oct. 6—Connecticut Section, at Sanford Barn, Hamden. Secretary, Donald W. Loiselle, Supt. of Supply, Bridgeport Hydraulic Co., Bridgeport.

Oct. 6–7—Intermountain Section, at Newhouse Hotel, Salt Lake City, Utah. Secretary, M. W. Snell, Supt., Power & Light Dept., Soda Springs, Idaho.

Oct. 9–12—Alabama-Mississippi Section, at Tutwiler Hotel, Birmingham, Ala. Secretary, Ernest Bryan, McWane Cast Iron Pipe Co., Box 2601, Birmingham, Ala.

Oct. 16–19—Southwest Section, at Galvez Hotel, Galveston, Tex. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

(Continued on page 8)

Coming Meetings

(Continued from page 6)

Oct. 19–21—Iowa Section, at Fort Des Moines Hotel, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

Oct. 20–22—New Jersey Section, at Madison Hotel, Atlantic City. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Oct. 24–27—Rocky Mountain Section, at Broadmoor Hotel, Colorado Springs, Colo. Secretary, Harrison F. Kepner, Vice-Pres., Dana Kepner Co., 550 Alcott, Denver, Colo.

Oct. 25–27—California Section, at Lafayette Hotel, Long Beach. Secretary, F. F. Watters, Hydr. Engr., State Bldg., Civic Center, San Francisco 2.

Oct. 26–28—Ohio Section, at Deshler-Hilton Hotel, Columbus. Secretary, J. Howard Bass, Henry P. Thompson Co., 1720 Section Rd., Cincinnati.

Change in Date

Nov. 2–4 (instead of Oct. 19–21 as formerly scheduled)—Chesapeake Section, at Sheraton Park Hotel, Washington, D.C. Secretary, Carl J. Lauter, 6955—33rd St., N.W., Washington, D.C.

Nov. 9–11—North Carolina Section, at Robert E. Lee Hotel, Winston-Salem. Secretary, T. Z. Osborne, Asst. Director of Public Works, Greensboro.

Nov. 13–16—Florida Section, at Galt Ocean Mile Hotel, Fort Lauderdale. Secretary, John G. Simmons, Plant Supt., Water Dept., West Palm Beach.

OTHER ORGANIZATIONS

Aug. 15–19—Course on "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Aug. 22–27—Seventh Internation Conference on Coastal Engineering, Kurhaus, Scheveningen, The Hague, Netherlands. Write: J. W. Johnson, Engineering Field Station, Bldg. 159, Univ. of California, Richmond 4, Calif.

Aug. 23–25—Symposium on water quality data collection and utilization, R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Director, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

Aug. 29–31—Symposium on water quality measurement and instrumentation, R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Director, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

Sep. 18–22—NEWWA. Queen Elizabeth Hotel, Montreal, Que.

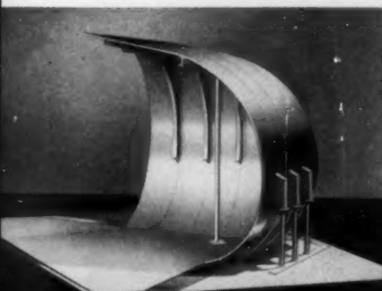
Oct. 2–6—WPCF, Convention Hall, Philadelphia, Pa.

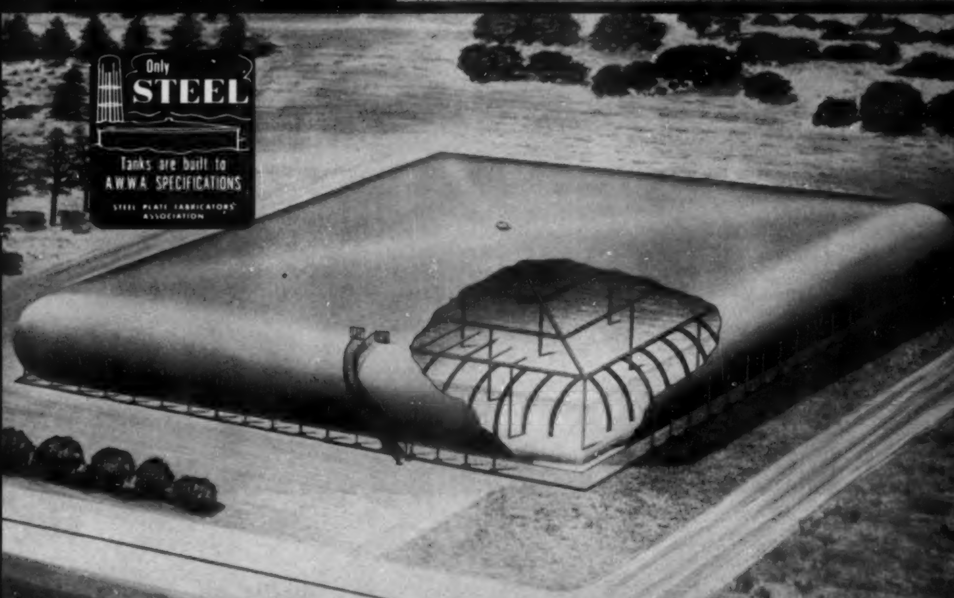
Oct. 10–14—Fall general meeting, AIEE, Chicago, Ill.

Oct. 17–21—48th annual National Safety Congress, Chicago, Ill., with sessions on industrial safety scheduled for Conrad Hilton, Pick-Congress, Sheraton Towers, Morrison, and La Salle hotels. Write: R. L. Forney, Secy., National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill.

Oct. 24–28—9th annual water works management short course, cosponsored by the Illinois and Indiana sections, AWWA, at Allerton Park, Monticello, Ill. Write: T. E Larson, Head, Chemistry Sec., State Water Survey Div., Box 232, Urbana, Ill.

Nov. 27–Dec. 2—Annual meeting, ASME, Statler Hilton Hotel, New York, N.Y.





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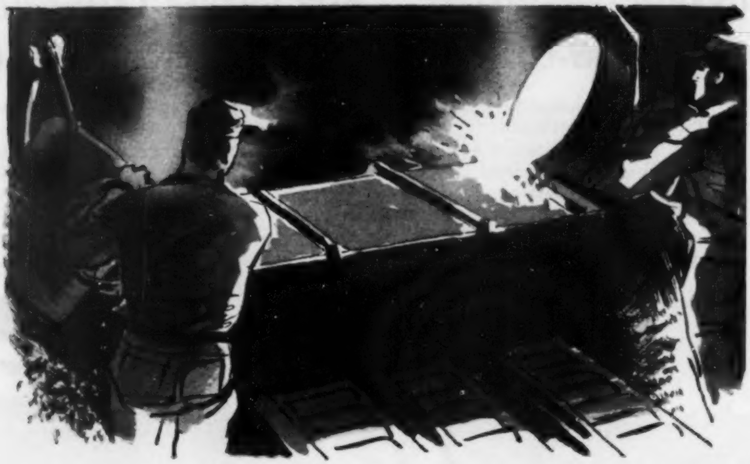

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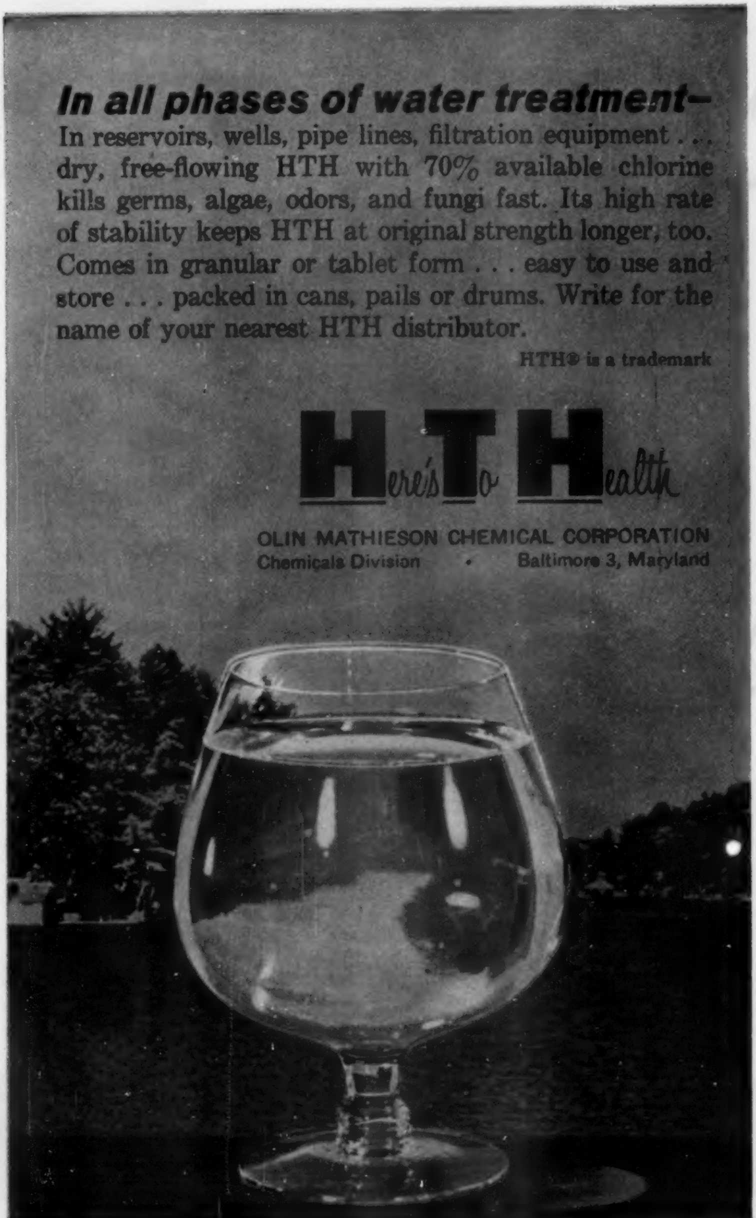
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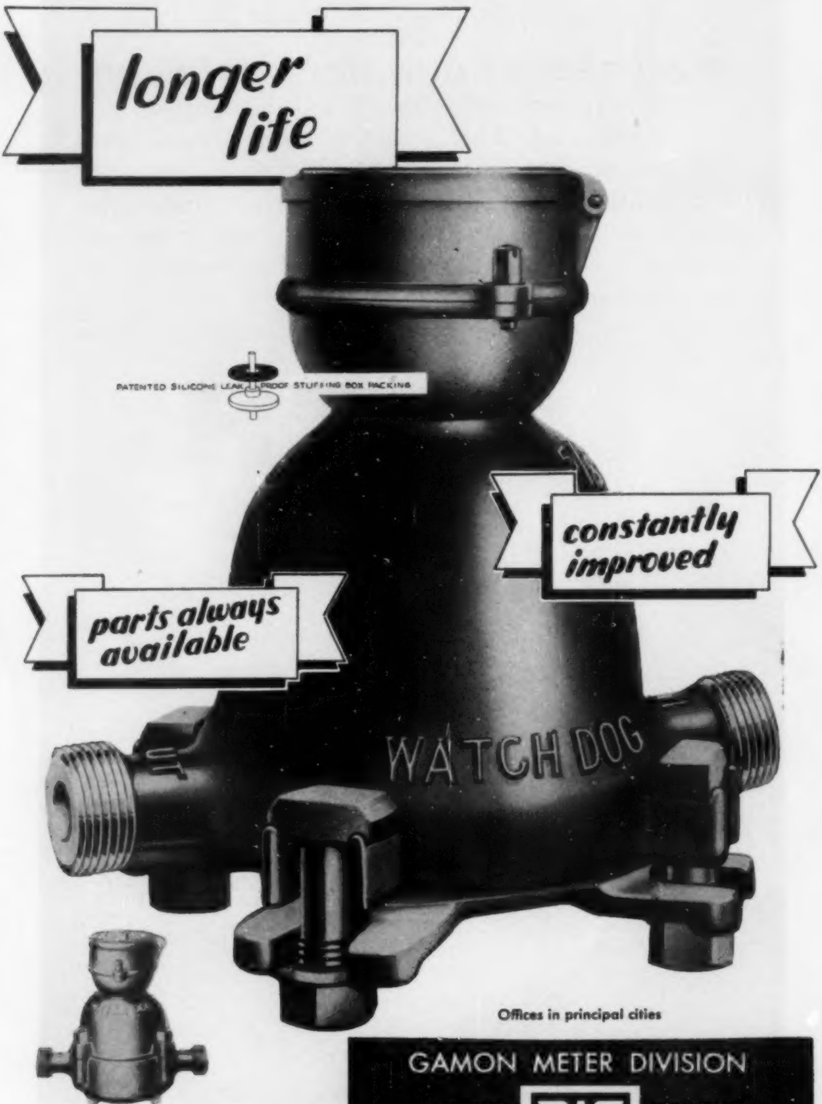
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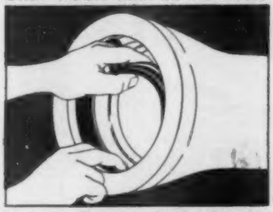
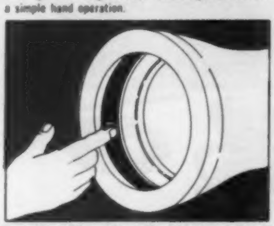
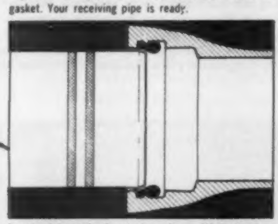


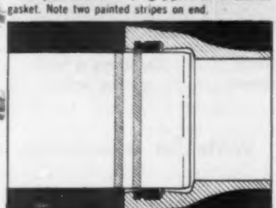
Insert gasket with groove over bead in gasket seat . . . a simple hand operation.



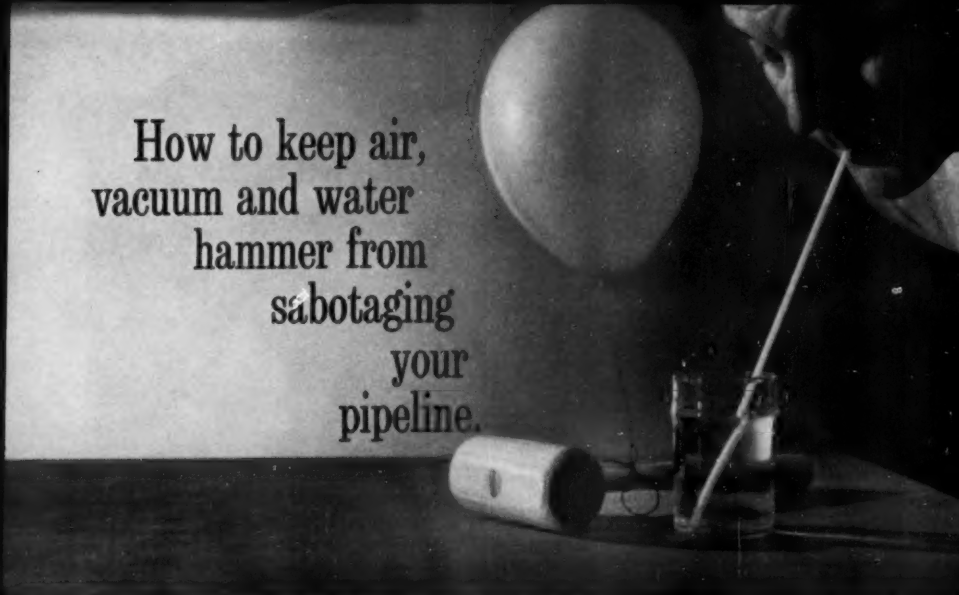
Wipe film of Tyton Joint* lubricant over inside of gasket. Your receiving pipe is ready.

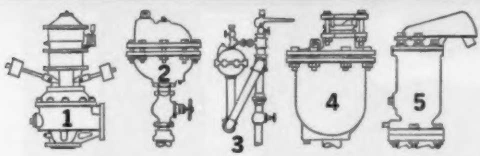


Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.



Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . . bottle-tight, permanently! The job's done . . . . fast, efficiently, economically. Could anything be simpler?





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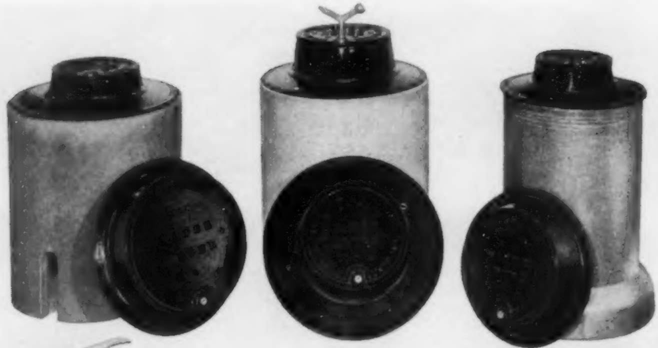

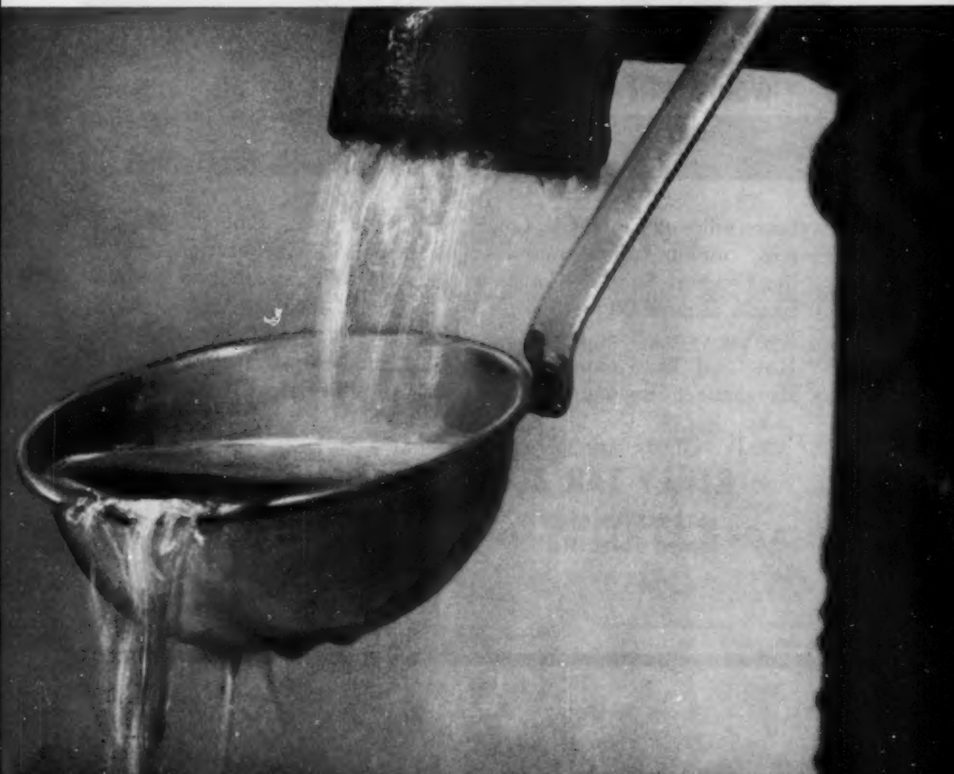


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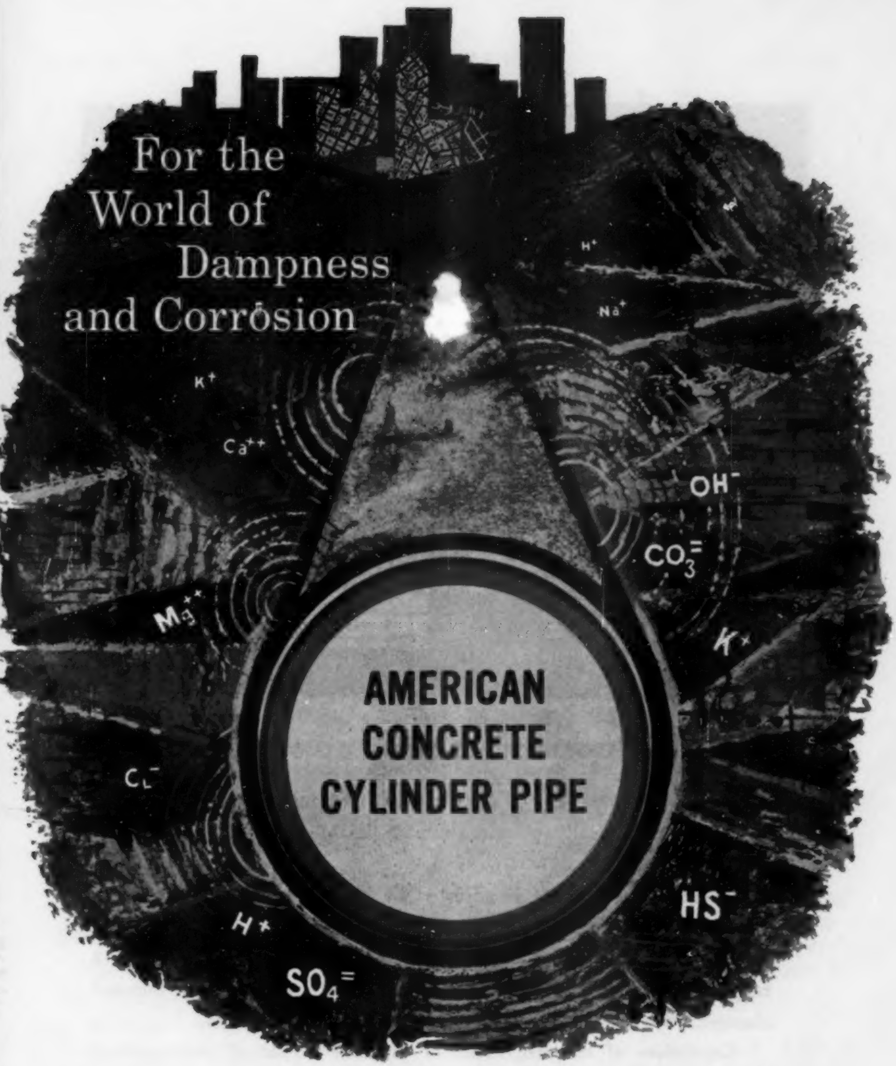

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Pollution and National Water Resources

Mark D. Hollis

An address delivered on May 17, 1960, at the Annual Conference, Bal Harbour, Fla., by Mark D. Hollis, Asst. Surgeon General & Chief Engr., US Public Health Service, Washington, D.C., and Pres., Water Pollution Control Federation, Washington, D.C.

AMERICAN society needs more water—more water to drink and much more water to produce the things its people eat, wear, and use. Water, the world's most plentiful resource, stands out today, as it always has, as a key to man's progress. To provide an adequate supply, in usable form, when and where it is needed, and to do all this at a reasonable cost, is now a critically urgent national problem.

Growth and Water Needs

There is no question about population growth or about the development of gigantic metropolitan complexes. There is certainly no question about industrial expansion and the accelerating avalanche of technologic advancements. More and more water will be required to support this growth. These are not fantasies any longer; they are the simple realities of the times. And they are further reasons, as I see it, for AWWA and the Water Pollution Control Federation (WPCF) to strengthen their close ties, the better to discharge their respective responsibilities—responsibilities that are now inseparably linked.

National authorities seem agreed on a gross water need in the 600-bgd range by 1980. This amounts to 1,800,000 acre-ft/day. At this rate, a week's water would flood all of Manhattan Island to a depth of approximately 1,000 ft, completely submerging the famous 70-story RCA Building; in fact, there would be enough depth to sail the *Queen Mary* right over it.

Nature of the Problem

Actually, the continental United States has enough fresh water. There are two major problems: that of distribution, both seasonal and geographic; and that of pollution, both biologic and chemical.

With respect to distribution, use of impoundments and aqueducts can do much more, from the standpoint of engineering, to distribute the available

water where and as it is needed. With respect to pollution, much more can also be done through sound engineering to conserve fresh-water resources for reuse. Both distribution and pollution control projects cost money, however. In time—and perhaps not such a long time—our present concepts and practices in these two fields will need significant realignments.

We must keep in mind that there are practical limitations of impoundments. For example, on many streams the impoundment networks already merge crest to toe. On other streams, major impoundments will bite quite deeply into agricultural areas. The relative value of water supply and agricultural uses of land must be determined. The partial balancing of fresh-water needs through major diversions between watersheds presents intriguing possibilities. It is possible, for example, to envision a network of giant power systems and canals fed by excess flood waters from such rivers as the Columbia and Missouri. It is even more enticing to think what might be done through diversion works fed by the world's largest fresh-water source, the Great Lakes. To make such projects feasible, cheap power would be the key. The potential for this we have, even though its realization may be some years ahead.

But before we become too ecstatic in our flights of fancy about engineering possibilities, we have to reckon with legal and political realities. Diversions of waters from natural watersheds introduce such fundamental questions as those of basic constitutional water law, property rights, and water rights doctrines. These must be resolved at the political, legal, and public policy levels. On the other hand, AWWA and WPCF can and should be much more active than they have been in influencing these decisions.

The possibility of weather modification and cheap methods of desalting sea water as means of satisfying fresh-water needs has intrigued scientists over the ages. One needs only study the present status of these sciences, however, to see that their practical applications in terms of providing major quantities are a long way off.

For the predictable future, reality would seem to dictate that, for the most part, we make the most of what water we have. This means that we must complete, basin by basin, the network of impoundments to conserve flood flows; that we must work toward the more equitable use of water; and, finally, that we must recognize that the most reasonable method of providing more usable water is to save more water. The best way to save water is to improve our scientific knowledge and tighten up our restrictions on stream pollution. Although the principle is simple, its achievement is not. First, we must have a few scientific breakthroughs in waste treatment technology. Economical methods of removing certain soluble molecules or ions must be found.

Growth of the Pollution Problem

Late in the 19th century, when construction of sewers in our urban areas was extensive, we moved filth, quite literally, from our doorsteps to the outskirts of town. It was dumped into the rivers with little or no treatment, until, in time, many rivers themselves became sewers. In a large measure we entrusted our own health to the water treatment facilities and let downstream neighbors fend for them-

selves. At the turn of the century, 24,000,000 Americans were served by sewers. Surface streams served as sources of drinking water for 2,000,000 people. Urban populations were small and the long distances between sewer outfalls and water intakes diminished the public health hazard. Fortunately, streams, if not overloaded, have the ability to cleanse themselves of normal household and natural organic pollution with time. By 1920, however, 47,000,000 people were served by sewers and 20,000,000 were using surface streams for drinking water. In many areas it became necessary to treat sewage before it was discharged. For the most part, such treatment was only to condition the waste so that the streams could complete the job with time.

By 1940, sewer systems served 70,000,000 people, and 40,000,000 were using surface streams for drinking water. Again, we made adjustments in treatment of sewage and further refinements in water treatment, but we held to the concept of minimum waste treatment and maximum use of the assimilation capacity of surface streams.

At present, 105,000,000 people are served by sewers, and 100,000,000 are dependent on surface streams for drinking water. The upsurge in numbers has accompanied the transition from rural to urban living. From now on, sewage outlets and water intakes will be wedged closer and closer together, and heavier demands will be placed on both sewage treatment and water treatment facilities. The margin of health safety is correspondingly thinner, and the job of providing a quality water, too, becomes much more difficult.

It should be kept in mind that even "complete" sewage treatment is still partial treatment; it is not "purification." Dilution by streams is still a major equalizer. Actually, on a national basis, for no year since 1910 have we removed, through treatment, as much pollution as has been added. The growth of the sewered population and the amount of industrial waste produced far outweigh the capacity of treatment facilities to remove pollutants.

New Pollutants

New pollutants present another complicating situation. Prior to 1940, city sewage was mostly natural organic material, household waste with its concentration of germs. Even industrial waste was composed mostly of natural organic materials. Today, on the other hand, metropolitan and industrial wastes include increasing amounts of new kinds of contaminants, such as synthetic organic chemicals and radioactive materials. The volumes of these complex wastes are spiraling upward. Many of the new contaminants persist for long periods, and, to a considerable extent, are not removed by conventional sewage and water treatment techniques.

We have much to learn about the behavior of the new substances finding their way into our streams, their effects on public health, aquatic life, and municipal and industrial supplies. The question of their toxicity adds to the age-old problem of enteric disease. The problems of water pollution are broadening to include a whole new array of pollutants. Recently there have been several technical articles on presence of chloroform-extractable compounds in samples from United

States streams. The data show that although the composite concentration of these synthetic contaminants is generally low—500 ppb or less—they are widespread. There were practically none prior to 1940.

Development of the basic intelligence on the present complex pollution is going to be extremely difficult, for it involves the matter of combinations of substances, of composites, and of synergisms. In all probability the health effects will be subtle, much less defined than those of germ diseases, and much more difficult to pinpoint. Toxicologists and epidemiologists must anticipate many new types of problems. Our present knowledge with respect to these exotic new substances is at a level comparable to the level of our knowledge about communicable disease back at the turn of the century. The differences today are the complexity and subtlety of the problem.

Need for Pollution Control

We all recognize that we cannot have all the advantages of modern technology—the magic of pushbutton living—without accepting some of the consequences. Just how clean we keep our water resources is a matter partly of definition. If our objective is absolute purity, we can easily spend ourselves out of progress. If, on the other hand, we think only of the cost of controls, we can just as easily economize ourselves out of safety and well-being. Between these two extremes come the difficult choices. In short, there are limits to what we can accept as progress. These are imposed by considerations of human well-being. The difficulty lies in identifying the limits and defining the subtle hazards. This difficulty is now heightened by the unparalleled rate at which our water problems are multiplying.

To say it costs too much to prevent excessive water pollution is simply foolish. But we do need a clear definition and understanding of what we mean by "excessive." Obviously, contaminants *must* be kept below levels of personal health damage. They *should* be kept at levels compatible with all legitimate uses of water. It is *desirable* to keep them within the bounds of aesthetic considerations. Each of these objectives has its price tag, and one can be sure that the higher the objective, the higher the cost will be.

Our present decade has already been labeled as the "Soaring Sixties." As we decide what our missions for the Sixties are to be, we need keep in mind that the problems of water supply and the problems of pollution more and more are becoming inseparable issues. By 1980, more than 160,000,000 Americans will depend on surface streams for drinking water. More than 200,000,000 will use the same watercourses for final disposal of wastes—not including industrial wastes.

This much we know: the United States has enjoyed world leadership in water and sewage works practice; our drinking water supplies are often referred to as the best in the world, the safest and the most dependable, and, incidentally, the least expensive. We have a real job ahead to keep them that way.

Responsibility of the Industry

Water supply is our business. This business now requires improved understanding and knowledge about the dependability and quality of the sources of our supplies. Today's problems of

pollution are different from those of 20–30 years ago, and tomorrow will bring further changes. Our standards for measuring and evaluating pollution and our waste treatment methods must be brought up to date and kept there.

We are not quite as confident as we once were that our barriers against all biologic and chemical hazards are adequate. We know there is a buildup in streams of conglomerates of exotic new chemicals and radioactive wastes. Admittedly, as yet there is no valid evidence that these substances are now endangering public health, but, unfortunately, this part of the problem is characterized more by what we do not know than by what we do know. Also, we must keep in mind the rapidity of change, for it is when we look ahead for a decade or two that some of these things have sobering implications and create a sence of urgency for research action now. Somewhere on this fantastic growth curve we are going to be in trouble if we are not ready; the question is how much time we have to get ready.

Through its leadership, AWWA has a continuing responsibility to see that water treatment practices are able to meet the challenging new problems. The water supply profession ponders the onrush of technologic developments and the future wall-to-wall population. Water needs will rise to astronomical figures, and, for the most part, we will have to get along with what water we have. This means, for many areas, extensive reuse of streams. Six-time reuse will be common for many streams within the next 10 years. Under such conditions, what will tap water be like? What will happen to other water uses and needs? Will present water treatment methods require substantial alterations, adjustments, or modifications? What can we expect in terms of scientific breakthroughs in waste disposal technology? These are timely and pertinent questions.

There seems little doubt that water supply and waste treatment will move front and center for special research attention in the Sixties. This means that AWWA and WPCF have a joint responsibility to use their influence and ingenuity to see that what needs doing gets done.

Public Opinion

We all know that water rate structures are not commensurate with the needs of the times. The problems ahead run the gamut from public apathy to public alarm. The problem of public apathy, I think, we all recognize. We have too long accepted public apathy toward the inseparable problems of water supply and water pollution. We have lived too long with less than our share of the public works dollar, and some of us have been guilty of sharing the public apathy toward water problems. In the matter of public alarm, the important point is for professional leadership to stay well advanced and well versed, so as to be able to influence public opinion. It must be kept in mind that public policy stems from public opinion. We must never allow ourselves to become more concerned with alarms of the public than with the basis or lack of basis for such alarm. Fortunately, once given a true picture the people usually come to the right conclusion. Our job is to see that the citizen gets all the facts. This job is complicated by the fact that the average citizen is simply too busy with his job and family to be

concerned with much else than his personal health and his pocketbook.

Conclusion

What do we really want our organizations to become? Our answer to this defines, I think, our real purpose and the goals we should seek to achieve. Can we resolve our own debates and state clearly what we believe is the best course to pursue in the varieties of perplexing questions now facing us? If we can, and if we can help point the way to better answers than have so far been found, using our combined force of persuasion to make them generally understood and accepted, whatever efforts we devote to the task will have been immeasurably justified.

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Activities of the Senate Select Committee on National Water Resources

Theodore M. Schad

A paper presented on May 18, 1960, at the Annual Conference, Bal Harbour, Fla., by Theodore M. Schad, Staff Director, Select Committee on National Water Resources, US Senate, Washington, D.C.

SOME time ago, there was a member of Congress from a rather conservative district in a Northern state where dollars must have been hard to get, who would habitually greet each huge new federal appropriation bill with the question: "where are we going to get the money?" As the author watches the forecasts of future water demands being worked out for the Senate Select Committee on National Water Resources, he is beginning to feel somewhat the same way about water: Where is it going to come from?

The United States always seems to be able to get more money, no matter how fast it is spent, but with all of man's scientific ingenuity he has not yet figured out an economical way to get more fresh water than nature provides. Perhaps some day he can; he may have to; but for the present he must plan water development—and, in some areas perhaps, use—on the basis of how much of the vital resource is already available. He cannot count on a scientific miracle to help him out.

Hope of a Breakthrough

Many people are building up hopes for an early breakthrough in research on desalinization of sea water or on artificial stimulation of rainfall. This, they hope, will lead to the development of techniques that will solve all of the nation's water problems. Although research in these fields must be kept moving ahead, the progress reports on these techniques filed with the Senate Select Committee by federal agencies give no concrete evidence that success is imminent. The continued efforts of scientists and engineers may eventually lead to a revolutionary discovery, and it is to be hoped that it will come soon, but, in the author's opinion, it would be a grave mistake to place any great dependence on the hope of an early solution to the overall water problem from either of these two sources. A major breakthrough, when it ultimately comes, will have been achieved only after long and arduous research into the innermost secrets of the water molecule and the atmosphere.

Approaching Shortages

The United States is rapidly approaching the time when it will need and use all the water it can get from every conceivable source and by every conceivable means: the conservation of streamflows; greater use of underground sources; salvage of previously used waters of every sort; and rigorous elimination of waste in storage,

transmission, and use. That the United States is already in a headlong rush toward such a time is indicated by the computations being made for the committee for projected demands between now and the years 1980 and 2000. When compared to the potential supplies, these figures indicate that by 1980—just 20 short years away—at least five of the 22 water resources regions into which the country has been divided for these studies will have generated demands that will exceed the total available supply, even with wide-scale reuse of water. This will necessitate the importation of water from distant river basins or, substantial increases in the efficiency with which water is used, the elimination of some water uses in deference to other, more essential uses. These regions are, of course, in the arid Southwest, but the committee is not in a position to release specific figures on them until the studies are completed and checked. The findings of the committee may have rather serious implications.

The remaining seventeen more adequately watered regions face the need to build systems of dams and reservoirs in order to gain almost complete control of river flows—a need that only the more arid regions have experienced until recently. The committee's nationwide survey of water needs and supplies, the first of its kind, shows that the United States is entering a new era—an era when it can no longer passively enjoy a natural abundance of water but must plan to create a sufficient supply.

Committee Activities

The results of the resources study will provide the primary basis for the report submitted by the committee to the Senate in January 1961. The report is to contain information on:

1. The nature and extent of needed water development between now and 1980
2. When and where development will be needed
3. What the pattern of development should be
4. What the economic limits on development are
5. What expenditures of public and private funds can be economically justified.

In short, the committee's task is to forecast national growth and social and economic changes for the next two decades, insofar as these affect or are affected by water. Because water is involved in almost every human activity this undertaking is of almost limitless proportions.

The committee hopes that its findings will provide an effective guide for determining the public policy and programs of resources development that will enable the best possible use to be made of available water. The committee is not likely to recommend specific projects; instead, it will probably indicate the nature and extent of development required for each river basin and recommend legislative policy that will assist in meeting those requirements.

Background Studies

Before it can make any recommendations, of course, the committee must obtain projections of future requirements and supplies for each river basin. These projections are being made for the committee by federal agencies concerned with resources development and cover the whole broad range of water uses and related activi-

ties, including pollution abatement, navigation, fish and wildlife, and recreation. Additional information is being gathered from various interested national agencies and from reports of states and territories.

Projections of needs and supplies are being assembled on a region-by-region basis by Resources for the Future, a highly competent foundation set up and endowed by the Ford Foundation, which is providing staff work and preparing a report for the committee as a public service. The study is under the direction of Nathaniel Wollman, on leave from the University of New Mexico, with the cooperation of staff members from the various federal agencies providing the projections.

Collateral studies are being made, under contract, by Edward A. Ackerman, an outstanding water resources authority, and by Abel Wolman and Associates. The committee has also enlisted the consulting services of Gilbert White, of the University of Chicago, a leading expert on flood control; William G. Hoyt, one of the country's pioneer hydrologists, who spent many years with USGS and the Department of the Interior; and H. C. Gee, formerly of the Army Corps of Engineers and now a consulting engineer in private practice.

Beyond this, each of the federal agencies concerned, along with the states and certain private or semipublic agencies, has been invited to make reports and recommendations on the water problems in its specific area of interest. All told, 32 studies and reports, covering various phases of water resources activities, are being prepared and published as background studies for the committee's report. In addition, the committee has held 25 public hearings in 21 states and in Washington, D.C., for the purpose of securing informed public opinion on national water problems.

Preliminary Indications

Most of the background reports are now completed, or nearly so, and their contents are revealing. In addition to the tremendous quantities of water that will be required to meet national growth and change in water uses, they show that preservation of the quality of the water will be equally important and difficult. In fact, the nation appears to be much better prepared, technologically and every other way, for providing the quantity of water needed than for preserving its quality.

The computations by Resources for the Future indicate that the flows needed for dilution of sewage and industrial wastes under present treatment techniques will be extremely high. In fact, dilution will become the controlling use of water in the highly congested, urban-industrial areas, such as in the northeastern part of the country, unless other means can be found to preserve the oxygen content of the streams. The USPHS computations of the amount of water required, based on extrapolations of various methods for computing the ability of streams to assimilate wastes, indicate that such a large quantity of storage will be required for dilution that new techniques for handling wastes will have to be developed as the most economical way of dealing with waste disposal.

As an example, the figures show that by 1980, the Ohio River Basin would require almost twice the 6,000,000 acre-ft of reservoir storage now available, just to provide enough flow to insure a reasonably clean river—that

is, a river averaging 4 ppm dissolved oxygen. This would still mean odorous and bad-tasting water at certain times and places, and survival of only certain species of rough fish. One could live with such water, of course, but the forecasted increase in the use of rivers for recreational purposes indicates that the American public may demand something better.

By the year 2000, the sewage and waste load would become so large, under present trends, that several times the currently available amount of reservoir storage would be needed to meet the dilution flow requirements necessary to preserve a dissolved oxygen content of 4 ppm. These figures are based on a medium population growth and on 90 per cent treatment of sewage and industrial-waste inflows with present treatment methods.

An increase in the degree of treatment by present methods would reduce the dilution requirements for maintaining the oxygen content of the stream, but after a certain point there is the further problem of increasing quantities of plant nutrients, nitrogen and phosphorus, which promote the growth of algae and place an even greater, secondary pollution load in the stream. This, then, becomes the controlling factor for determining dilution requirements as the 85–90 per cent treatment level is exceeded. Then, too, there is the problem of chemical wastes, synthetic detergents, insecticides, and other pollutants not removed by present methods of treatment.

Altogether, the studies indicate combined national water needs by 1980 will approach the 600-bgd supply which some engineers recognize as the practical limitation on how much water can be made available with present development techniques. This is about half of the average runoff of all streams in the United States.

Reuse and Waste Treatment

It can be seen that the question "where is the water going to come from?" is by no means irrelevant. The answer, the only practical answer now, is that the nation is going to have to use the available water over and over again; cleaning it up each time it is used. Of course, much of the total use, possibly half of it, will be as cooling water for electric-power plants. This use leaves no contamination, although it does complicate the pollution problem by causing stream temperatures to rise.

If water development is planned wisely, based on a pattern that will ultimately lead to full conservation and use of the waters of each basin, if planning is supplemented with proper management of water resources, there should be a sufficient supply in most places, although not enough for all the things people will want to use water for in certain areas.

The quality of the water, however, is another question. It is evident that present methods of treating sewage and industrial wastes must be reevaluated. As USPHS has advised the Select Water Committee, new treatment processes, probably based on entirely new concepts and principles, may be required.

Although the committee cannot predict what will be found to be the best solution to the problem of providing sufficient clean water, it does appear that widescale elimination of biologically inert matter left over from present waste treatment methods will generally be required as an alternative to

committing tremendous flows of clean water for dilution. Presently known methods, such as lagooning of wastes and rapid oxidation, may come into increasing use. Beyond this, it appears that a determined effort in research and development in pollution abatement will be needed to develop new ways of handling waste.

Even if new methods are developed, however, and treatment of sewage and waste is so perfected that only clear water is returned to the streams, full conservation and regulation of the waters of most if not all of the nation's important river systems will still be needed ultimately.

The time will soon come when saying that a man spends his money like water will no longer be a way of describing him as improvident; for man is now entering a period when he will have to spend water as he should spend his money—to get as much as possible from the most sparing use of this vital, limited resource.

Coagulant Aids for Potable-Water Treatment

The USPHS Technical Advisory Committee on Coagulant Aids for Water Treatment has added the following products to the list of those that may be used for water treatment—in the concentration recommended by the manufacturer—without adverse physiologic effects on the consumers: Mogul CO-980, Mogul CO-982, and Mogul CO-983, manufactured by North American Mogul Products Co.; Permutit Wisprofloc-20 (identical to and replacing Permutit 68), manufactured by the Permutit Co.

The committee's findings bear only on the health aspects of the use of these products and do not constitute an endorsement or indicate their effectiveness in the proposed use. The names of other coagulant aids on the committee's list were published in the February 1959 issue (p. 233), the May 1959 issue (p. 574), the January 1960 issue (p. 152), and the April 1960 issue (p. 441) of the Journal.

Water Resources and Conservation in Florida

John W. Wakefield

A paper presented on May 18, 1960, at the Annual Conference, Bal Harbour, Fla., by John W. Wakefield, Director, State Dept. of Water Resources, Tallahassee, Fla.

FROM the point of view of water supply, Florida is truly a great paradox, for, although it is a land with an average annual rainfall of more than 50 in., and, in most of the state, this rainfall is fairly well distributed throughout the year, irrigation is employed to a greater extent than in almost any other eastern state. Tens of thousands of fresh-water lakes are available to provide water storage, and yet there is a shortage of surface water during dry periods. Florida has one of the great aquifers of the world, discharging billions of gallons of water a day to the surface through springs and flowing wells, but the recharge of ground water is so great that only a very small percentage of the annual rainfall runs off in streams.

Geologic History

The geology of the Florida peninsula was formed by repeated inundations by the sea which laid down layer upon layer of clastic and carbonate deposits. In at least three separate instances, the newly formed deposits were exposed on the surface, eroded by surface runoff and again inundated to receive fresh deposits. The greatest of these are the Ocala limestones of Eocene age which make up the bulk of the Floridan aquifer. The surface of the Ocala formation became exposed and was eroded by surface streams only to be flooded again by a rise in the ocean level. During the Miocene age, the practically impervious Hawthorn formation was deposited on top of the Ocala, conforming to the hills and valleys remaining when the Ocala was submerged. Again, much of the peninsula was exposed to the effects of erosion and subsequently submerged to receive fresh deposits. These most recent strata are the unconsolidated sands and rocks forming most of the present surface.

There are numerous other rock deposits which enter into the geologic makeup of Florida. In the southern part of the state, the Hawthorn formation, a rather dense stratum of little water-bearing value, is overlain with a very porous limestone known as oolite, which comprises the Biscayne aquifer. The oolite formation is, in turn, overlain in most areas with recent sands and in many wet areas with peat or muck deposits. In some areas, however, the oolite is exposed on the surface.

The so-called "panhandle," or western part of the state, and the lower peninsula are as unlike as two adjacent areas could possibly be. From the western edge of the valley through which the Suwannee River meanders, to Mobile Bay in Alabama, the lack of the numerous lakes which characterize the peninsula is noticeable. Although

still underlain with porous limestone, which outcrops near Marianna and in Wakulla County, the area is mostly characterized by rolling clay hills bordered by a coastal plain, which may vary in width from very narrow to 30 mi or more. Along the base of the highlands, the porous limestone is at or near the surface, and a number of large springs discharge hundreds of gallons of water per minute.

Hydrologic Features

There is a definite interrelationship between Florida's surface topography and streamflow on the one hand and the underground limestone formations and ground water flow on the other. Most of Florida's lakes were formed by structural collapse of underground limestone strata. Much of the dry-weather streamflow is a result of ground water discharge. Conversely, the flat topography and porous overlying sands allow maximum recharge of ground water from surface sources by downward leakage. In addition, there is recharge through sinkholes leading directly into deep underground limestone strata. It is not uncommon for surface streams to be formed by a group of springs, only to disappear again into a limestone sinkhole a few miles downstream.

Because Florida's surface sands are highly porous and allow waters to trickle readily into deeper strata, irrigation is employed extensively for watering crops of citrus fruit and winter vegetables. The Florida Water Resources Study Commission [1] estimated that more than 742,000 acres were irrigated in 1956 and that this would increase to 1,380,000 acres by 1970, for a consumption of 2,465,000 acre-ft of water annually.

The porous nature of the top soil and the flat topography also account for the relatively low stream runoff. The Oklawaha River, for example, at Sharpes Ferry above Silver Springs Run, has a runoff factor of only 0.37 cfs/sq mi, whereas at Orange Springs below the inflow from Silver Springs the factor is 0.83 cfs/sq mi. The 0.37 cfs represents an annual runoff of only 292,000 acre-ft resulting from rainfall averaging 2,933,300 acre-ft per year in the river valley. Evapotranspiration accounts for a loss of 1,950,000 acre-ft per year, leaving 983,300 acre-ft to percolate underground, probably to reappear to some extent in Silver Springs.

The dominating water-bearing stratum of peninsular Florida is the great Floridan aquifer. This huge expanse of highly porous limestone reaches from the Piedmont foothills of South Carolina and Georgia and underlies the entire state of Florida. It is formed principally of limestone of the Ocala group overlain by the Hawthorn formation. The upper surface of the water-bearing stratum is a somewhat warped inclined plane, the elevation of which varies from 80 ft above sea level in the area around and northwest of Ocala to 1,200 ft below sea level at the extreme tip of the peninsula and in West Florida in the vicinity of Apalachicola.

The thickness of the Floridan aquifer is not well established, but it is known to be several hundred feet. Figure 1 shows the height to which water will rise owing to artesian pressure in a well cased into this aquifer. This piezometric-surface map is taken from a more detailed piezometric-surface map [2] prepared by USGS in cooperation with the Florida Geological Survey. It shows a low-pressure

or discharge area in a saddle across the state in the vicinity of Ocala. The discharge occurs because in this region the Floridan aquifer is close to the ground surface and the water under artesian pressure readily breaks through to the surface.

Several large springs are located along the saddle. Table 1 lists the largest of these together with the county in which they are located and their average, maximum, and minimum discharges.[3]

The daily discharge of the springs of these five counties alone averages nearly 2 bgd. This is more than twice the total estimated municipal and domestic water consumption for the state of Florida in 1970.

The artesian-pressure trough across the middle of the peninsula serves as a barrier, preventing water in the artesian aquifer north of the saddle from reaching the area south of the saddle. As the artesian aquifer south of the saddle has a greater pressure than that within the saddle, ground water flow immediately south of the saddle is toward the north. All of the ground water in the southern half of the peninsula comes from recharge within the same area.

The northern half of the state receives very large quantities of ground water which enter the aquifer in other states. There is no way to estimate this quantity, but measured discharges from springs both in Alachua County and north of it account for an average of more than 1,600 mgd. This is probably only a small percentage of the discharge into the Gulf of Mexico and the Atlantic Ocean.

Resources and Conservation

Before the influence of man was felt in Florida, nature handled the water from the torrential tropical storms by providing shallow expansion areas into which the overflowing lakes and streams could spread. The great artesian aquifers were, and still are, fed from elevated plateaus in which the water is held in numerous lakes and swamps, thus providing time and energy for the water to trickle downward into the porous limestone. By storing water in this way, nature also provided water for the relatively long dry periods.

The Florida Everglades, into which Lake Okeechobee overflows, is the largest of the expansion areas. Similar smaller areas lie along the upper

TABLE 1

Flow Data for Selected Springs of Central Florida

Spring	County	Flow—*mgd*		
		Avg	Max.	Min.
Silver Springs	Marion	500	756	419
Rainbow Springs	Marion	452	599	315
Fannin Springs	Levy	70	88	51
Manatee Springs	Levy	109	141	88
Weekiwachee Springs	Hernando	103	149	68
Homosassa Springs	Citrus	120	143	91
Blue Springs	Volusia	104	188	40

St. Johns River, along the west shore of Lake Apopka, along the Kissimmee River, and in a great former lake bottom more than 100 mi long, lying between the present Withlacoochee and Oklawaha rivers.

Soon after Florida gained statehood, man began to look toward these rich overflow lands for profit. Almost without exception, they are rich in organic soil and promise high agricultural productivity. As a result, flood plain development has been carried on with great vigor and much success. The Everglades agricultural area and other similar but smaller areas have become a major source of winter vegetables for the populous eastern half of the United States. The annual gross income from truck crops in Florida is more than $158,000,000. All of this has been accomplished at a price, however, for in order to put the area into crops, the overflow lands had to be diked and drained, reducing the storage areas for flood waters.

Florida's population growth during the past decade has been nearly phenomenal. The building of millions of homes and hundreds of miles of streets and highways has increased both the speed and the quantity of surface runoff. Construction of dwellings in the lowlands along the waterways seriously reduces the range of surface water fluctuations formerly available.

Recreational demands require lakes that do not go dry and streams with sufficient depth for small-boat navigation all year round. Recreation has become a major business in Florida. Florida's available waterways together with the shoreline and climate are major factors in a four-billion-dollar-a-year tourist business.

All of these economic changes are good and all must be continued, but, at the same time, ways must be found to store enough water in wet seasons, without incurring damaging floods, to last through the dry seasons that inevitably follow The myriads of fissures leading to the great porous limestone aquifers must be kept full of water, if the unalterable discharge of ground water into the sea is to continue without lowering the water table and permitting intrusion of salt water.

Flood Control Projects

The problem of replacing lost storage areas is made more difficult by the lack of natural relief. The highest point in the state is only about 300 ft above sea level, and most of the highly populous coastal areas are within 25 ft of sea level. The Central and Southern Florida Flood Control District has coped with this problem by building dikes around large areas of the Everglades and around Lake Okeechobee. By using the lake for storage, while discharging surplus water through the St. Lucie and the Caloosahatchee canals, the Corps of Engineers and the Flood Control District are undertaking to prevent flooding of adjacent agricultural and urban areas. At the same time, they are attempting to provide sufficient holding and discharge capacity to permit flood control in the Kissimmee River Basin and on other tributary streams.

Levees isolate the great Everglades from Lake Okeechobee. To provide water control within the Everglades agricultural area, the Corps of Engineers is building and the Flood Control District will operate huge artificial water conservation areas totaling more than 1,500 sq mi. Several large pumping stations, including one with the largest self-powered pumps in the world, will lift water from the agricul-

tural area to the conservation area in wet weather and will pump back into the agricultural area for irrigation during droughts. The project is now in its eleventh year of construction and operation, and its cost through the fiscal year 1959, including maintenance and operation, totaled approximately $69,000,000. This is one-fifth of the estimated cost of construction and operation during the 50-year period it is believed will be required to complete the project. The cost is shared by the federal and state governments and by local property owners.

The benefits of this huge nineteen-county project, in addition to flood control, include water conservation for agriculture, industry, municipalities, recreation, navigation, and blocking of salt water intrusion. In 50 years, the benefits are expected to exceed the

Fig. 1. Principal Streams of Florida

Shown are the principal Florida streams discussed in the text. The Green Swamp area is circled with a heavy, broken line.

cost by a ratio of better than two to one.

Efforts have been made by local agencies to provide for water conservation in other areas of the state. Recreation and water conservation and control authorities are operating in Orange and Lake counties, and planning is underway in Sumter and Alachua counties. Multicounty districts have been organized, and planning is underway in the Peace and Suwannee river valleys; the Dead Lakes Water Control District in Gulf and Calhoun counties is already in operation.

Green Swamp Area

Local efforts have been encouraging, but the state is developing faster than the water control districts. The Florida Department of Water Resources was created by the 1957 legislature just about the time that the Oklawaha Basin Recreation and Water Conservation and Control Authority of Lake County was beginning operation. The Oklawaha River is one of four major stream basins rising from a flat, swampy plateau in west central Florida, known locally as Green Swamp. Realizing the inadequacy of their control measures without controlling the discharge from Green Swamp and knowing that the Green Swamp area extended beyond their authority, the Lake County water control board asked the Department of Water Resources to investigate the possibilities of water control.

The Green Swamp study is now in its second year and has already proved to be highly important. The basins of the Oklawaha, Withlacoochee, Hillsborough, and Peace rivers meet in the Green Swamp area (Fig. 1 and 2). This area, which is the location of the piezometric high for the southern half of the peninsula, is the major recharge area for this sector of Florida.

Based on incomplete data recently reported by USGS, working in cooperation with the Florida Geological Survey, a piezometric line indicating ground water levels of 130 ft above sea level has been drawn. The highest surface water within the area of study is that of Lake Mattie, Lake Van, and Lake Lowery, all lying along the southeastern edge of the swamp. These three lakes normally stand at 132 ft above sea level and discharge to the north into the Oklawaha River Basin.

The western portion of the swamp normally drains into the Withlacoochee River. The eastern portion usually drains into tributaries of the Oklawaha River. Most of the streams shown in Fig. 2, however, are heavily vegetated swamp runs and are very closely interconnected. Thus, for example, a heavy rainfall in the Lake Lowery region would probably cause discharge into tributaries of the Withlacoochee River as well as those of the Oklawaha. On the other hand, a heavy rainfall slightly to the northwest would probably reverse the direction of flow in the interconnecting streams.

A recent geological report by White [5] indicates that the Green Swamp area, along with the entire plain extending northward from Green Swamp between the ridge west of the Withlacoochee River to the ridge east of the Oklawaha Basin, probably was at one time a great shallow lake about 100 mi long and 20 mi wide. The original path of discharge is believed to have been through the southwest corner into the Hillsborough River. In the not too remote geologic past a structural failure in the northwest corner of the

lake allowed the water to break through the ridge to the Gulf of Mexico in the vicinity of Dunnellon. This was a shorter path to the Gulf and deep enough to permit drainage of the lake.

This saddle is still in evidence today. When heavy rainfall causes the Withlacoochee River to rise more than 4 ft above its normal level, water overflows the saddle and discharges into the Hillsborough River.

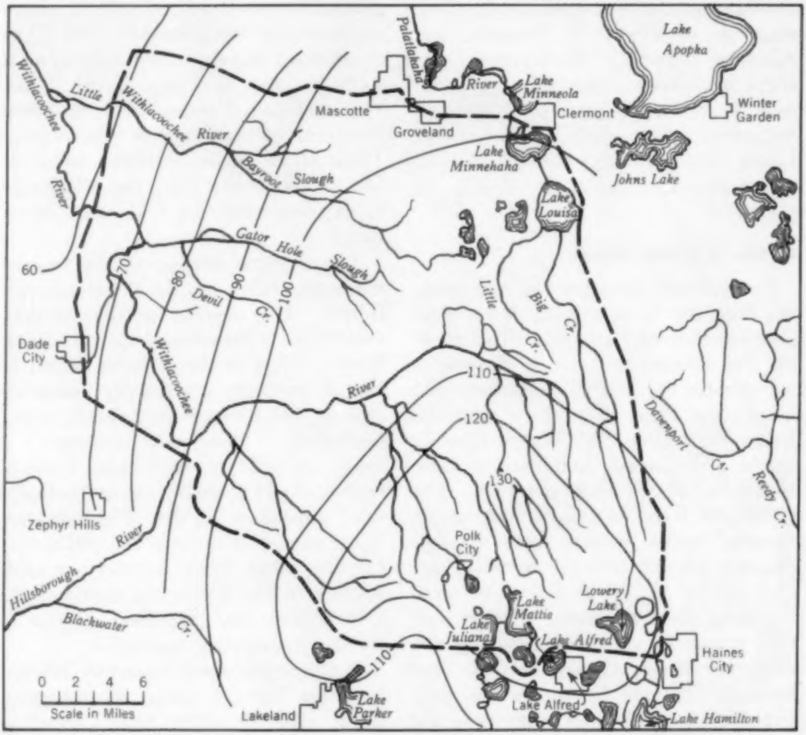

Fig. 2. Green Swamp Area

The boundary of the Green Swamp is represented by the heavy, broken line. Piezometric contours are given in feet above mean sea level.

The rushing waters draining along the western ridge formed the Withlacoochee River flowing to the north, and a shallow saddle was left separating the headwaters of the Hillsborough River from the Withlacoochee River.

In Green Swamp and the upper reaches of the Oklawaha River Basin, there are thousands of shallow depressions in the old lake floor normally filled with water and covered with swamp vegetation. There are hun-

dreds of open bodies of water ranging in size from lakes of a diameter of 6 mi to ponds smaller than an acre.

Aerial photographs reveal a series of low parallel sand ridges which probably once were offshore reefs and beaches when the area was under water. Separating the ridges are long swamp runs, generally sloping from north to south, through which the runoff meanders.

The fourth watershed in the complex, that of the Peace River, starts in a series of lakes lying along and slightly lower than Lake Lowery, Lake Van, and Lake Mattie. There is no dry-weather surface discharge from the Green Swamp into these lakes, but their dry-weather base flow undoubtedly results from ground water discharge originating in the swamp.

The importance of water conservation in this area, which until now has been provided naturally by swamp vegetation and flat slopes, is obvious. Both streams and aquifers are dependent on storage during wet periods to overcome losses during dry periods.

1960 Flood

The need for water control as an aid to flood control has only recently been dramatically illustrated. The year 1959 was the wettest year of record in this area. All of the streams were above or near flood stage almost continuously. Early in 1960, above-normal rainfall kept the lakes and aquifers full of water. This was the condition prevailing on Mar. 15, 1960. During the next 3 days an average of 10 in. of rain fell on approximately 10,000 sq mi of the state. The affected area crossed the state from Tampa to Orlando and reached north and south from Ocala to Lakeland. The resulting flood in the Hillsborough, Withlacoochee, and Oklawaha river basins was the worst ever experienced in the area. Hundreds of families were driven from their homes, thousands of acres of farmland were flooded, and roads and railroads were washed out. The Corps of Engineers conservatively estimated the damage to be $20,000,000.

There is no doubt that 10 in. of rain in 3 days will cause floods almost anywhere. Florida has had very heavy rainfall many times in the past, but this rainfall set new runoff and stage records on all three streams. It appears that the flood damage was aggravated by attempts of private-property owners to drain flooded lands during the preceding wet year. There were no controls in the upper watershed and all the waterways were already full of water owing to recent rains. In addition, ditching and clearing had provided for much faster runoff and shorter times of concentration.

Need for Controlled Storage

It should be obvious that controlled storage is the only answer to the problems of both drought and flood. Attempts to increase the runoff capacity of the streams without adequate control simply increase the drought problem. On the other hand, continued attempts to reclaim wet lands in the upper watershed can only aggravate both problems. The real solution lies in controlled storage coupled with enough canals to provide both ready control of the water at any stage and selective discharge to the four major river basins.

The accomplishment of controlled storage in the Green Swamp area should be fairly simple from a design standpoint, but the magnitude of the land area involved would make such a solution very expensive. The area en-

compassed within the perimeter shown in Fig. 2 is about 800 sq mi; the wet area is about 200 sq mi. The program conceived by the Department of Water Resources is to obtain ownership of, or flowage rights to, the frequently wet lands, leaving the dry land for continued use. Storage would be provided between the present annual low water level and normal high water level. A series of low dams blocking the swamp runs between the existing ridges coupled with controlled discharge and canals from one to the other would permit storage or discharge at will. Present and future road and railroad embankments would be utilized to control flow in the Withlacoochee River. Controlled outlets to the Hillsborough and Peace rivers would add flexibility and other benefits, especially during droughts. Further controls on the lower reaches of all four rivers would allow increased discharge in time of flood and water conservation in time of drought.

Efforts are underway to develop a cooperative federal, state, and local project, similar to the Central and Southern Florida Flood Control District, to encompass the 14–15 counties through which these streams flow. A Corps of Engineers reconnaissance study has been requested and appears certain of accomplishment. A steering committee of local political leaders has been formed to promote and introduce suitable enabling legislation in the next session of the state legislature. In the meantime, the Florida Department of Water Resources is coordinating its preliminary study with that of USGS and other state and federal agencies.

Conclusion

Florida has more water above, below, and around it than any state in the union, and enjoys the fortunate position of having ample supplies of water to meet all foreseeable needs. This fortunate position can, however, be changed by unwise drainage practices and by overdevelopment without compensatory controls.

The Central and Southern Florida Flood Control District is well started toward accomplishing control in the southeastern part of the state, but floods and droughts in recent years indicate that similar measures are needed in the west-central and southwest sectors of the state.

Studies indicate that opportunities for water control exist in the Green Swamp plateau in west-central Florida, and efforts to take advantage of these opportunities are now being planned.

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Problems of Waste Disposal and Ground Water Quality

Matthew I. Rorabaugh

A paper presented on May 16, 1960, at the Annual Conference, Bal Harbour, Fla., by Matthew I. Rorabaugh, Dist. Engr., Ground Water Branch, USGS, Tallahassee, Fla. Publication of this article has been authorized by the Director, USGS.

THE problems associated with waste disposal and its effects on ground water are many and complex. Wastes get into underground reservoirs intentionally through septic tanks, injection wells, ponds, sinks, and spreading basins and unintentionally by seepage through retention basins thought to be tight; failure of structures due to improper design, poor construction or inspection, lack of maintenance, or accidents; seepage of irrigation water; recharge from rainfall contaminated by wastes in the atmosphere; and infiltration of surface waters carrying wastes.

Wastes produced in the manufacture and use of plastics, detergents, insecticides, and other chemical products cannot be completely removed from water by standard methods. These wastes may eventually reach fresh-water aquifers in quantities sufficient to cause serious problems.

Radioactive wastes are an even more serious problem. Although it is expected that methods of treating most chemical wastes will be developed through an accelerated research program, there is no way to destroy radioactivity. The Reactor Development Division of the AEC, in cooperation with USGS, and other agencies, has been intensively studying the problem of water disposal.[1] Regardless of how safe the method of disposal may be, there will be an element of risk of aquifer contamination as a result of accidents. The risk is reduced to a minimum where careful studies of the geology and hydrology are made as a basis for selecting plant sites, and where provision is made for containment and removal of radioactive material in the event of an accident.

Movement of Fluids

Although problems of liquid disposal to the underground are similar in many respects to problems of ground water development, there are important differences. To solve either problem adequately requires knowledge of the extent and thickness of the aquifer, its properties and hydrologic characteristics, the nature and hydrologic characteristics of underlying and overlying beds, areas of recharge, areas of discharge, direction of movement, and the chemical and physical properties of the fluid.

Much of the theory of ground water movement and well field design is based on Darcy's law—that velocity is equal to a constant permeability times the hydraulic gradient. The equations, based on laminar flow through ideal isotropic material, are practical for most problems of ground water devel-

opment, which deal with a single fluid. For problems of waste injection and movement of wastes underground, the equations provide only approximate answers on a bulk basis. The concept that an injection well behaves in the same manner as a pumped well, except that there is a buildup of head instead of drawdown, is approximately true for computing quantities that might be recharged. In order to predict where the waste will go and its rates of travel, however, it is necessary to learn more about what happens underground when a fluid different in pressure, temperatures, density, or dissolved chemicals is injected into an aquifer.

Head Differences in Aquifers

In cooperation with state and other agencies, USGS has made current meter flow studies in deep wells. In some wells it is found that there is internal circulation. Water enters the well bore, flows upward or downward, and moves outward into another zone of the aquifer. Flows of several hundred gallons per minute and head differentials of as much as 6 ft have been observed in limestone aquifers in Florida.

To demonstrate the need for geophysical studies and for better definition of the pressure distribution in aquifers, the reader is invited to consider a hypothetical well 500 ft deep: A current meter survey showed that water was entering the well at a depth of 450–500 ft, was flowing up the well bore, and was leaving the well at a depth of 200–250 ft. A second current meter survey was made while the well was being pumped; water entered from the bottom zone of the aquifer; part left the well through the upper zone and part went to the pump. In this case all the production came from the lower zone. If the well were recharged at a rate equal to the pumped rate, all the injected fluid would enter the upper zone; there would be a diminished inflow from the lower zone which would move up the well and discharge into the upper zone. If the upper zone were fresh and the lower zone salty, tests made of the water being pumped would show salt water. Also, a conductance survey would show salt water in the well bore below 200 ft. On the basis of these data, a permit might well be granted to use the well for disposal purposes, but, if the proposal were carried out, the injected water would all enter the fresh-water zone.

Density Problems

The difference in the densities of the waste and the natural fluid in the aquifer has a very important effect on the movement of the waste. If a heavy waste is injected into a fresh-water zone, the waste does not move horizontally outward from the well as assumed in the equations used in practice. There is a downward component of flow caused by gravity, so that the waste fluid tends to settle and moves outward a greater distance at the bottom of the aquifer than at the top. If recharged is stopped, the "slug" of waste will continue to settle in response to gravity. Similarly, a light fluid injected into a heavier fluid will tend to float and spread faster along the top of the aquifer. Under proper conditions, such as a dip in the stratum, natural ground water gradients, and density differences, it is possible for the waste to move in a direction opposite to the direction of ground water flow. Equations and a number of diagrams for such selected conditions have been published in an article by Hubbert.[2] The situation is not

unlike that found in sea water encroachment problems, in which a sea water wedge moves inland below at the same time that fresh water moves seaward above.

Temperature Differences

Temperature of wastes is an important factor to consider, for several reasons. Most important is its effect on other uses of the water. In many areas intentional injection of used water is permitted if a closed system is used. Water may be pumped from a well, used for heat exchange purposes, and then injected, at a higher temperature, into a fresh-water zone. At the time regulations were developed to prevent bacterial or chemical pollution, heat was not a problem and was not considered a contaminant. With the rapid growth of air-conditioning and industrial cooling demands, however, warm-water injection is causing aquifer temperature to rise locally in congested areas. If ground water resources are to be developed effectively, it will be necessary to develop criteria for determining the practicability of warm-water injection. Experience over the past 25 years shows that warm water can be successfully injected in large amounts in areas having thick-layered aquifers if the pumped well is at one level and the injection well is at a higher or lower level. Experience shows also, however, that in thin aquifers or aquifers having good vertical permeability, the warm water frequently reaches nearby pumped wells. Detailed geologic and hydrologic exploration is needed to estimate the probable success of warm-water injection.

Temperature also affects the movement of fluids. Density differences related to temperature may cause flow patterns to deviate from those expected. Also, viscosity varies substantially with temperature. Flow rates increase about 1.5 per cent per degree Fahrenheit; water at 100°F will flow about 1.5 times as fast at a given hydraulic gradient as water at 70°F.

Diffusion

Much of the theory for two-fluid systems is based on the assumption of a thin or sharply defined interface; in other words, the fluids are considered immiscible. Study of salt water encroachment in the Miami area [3] shows that there is a zone of diffusion of considerable thickness between the fresh water and the sea water wedge. On the basis of field studies at Miami and laboratory studies at the University of California,[4] it may be concluded that there is no sharp line of separation between a body of waterborne waste and the natural water. Diffusion or mixing occurs along the front, the magnitude of the diffusion zone being related to velocity, frequency and amount of agitation (effects of barometric changes, earth tides, ocean tides, and recharge from rainfall), molecular diffusion, and nature and size of pore spaces and their degree of interconnection. From most wastes, the contamination would be spread to points farther from the source than would be computed from bulk equations. From warm wastes, heat is absorbed by the aquifer. Chemical wastes may adhere to or react chemically with the porous material. In the two latter cases, a lag in travel time develops as the diffusion zone widens.

Recharge in Miami

An example of complex conditions is found in the Miami area. At the present time (1960) permits to re-

charge with swimming pool water, laundry water, and air-conditioning water are granted if the injection well is cased into salt water. The salt water is part of the sea water wedge. Studies show a cyclic flow of sea water having a landward direction in the salt water zone. A slug of fresh-water waste is thus given a landward component of flow. The density of sea water is 64 lb/cu ft; that of the waste may be about 62.5 lb/cu ft. The difference results in an upward force of 1.5 lb/cu ft. Vertical permeability is exceptionally high. If the recharge rate were low, the waste would move upward and landward into the zone of diffusion. As soon as it reached the zone of seaward flow it would begin moving toward Biscayne Bay. Thus, if the recharge rate were low, the waste would probably not reach the zone of fresh water. If recharge rates were high, the waste would move outward from the well and then upward, owing to density difference. If the volume were too large to be rapidly diffused, some might rise into the fresh-water zone. The complications in this problem are such that a solution cannot be computed by available methods. A field test with tracers would very likely shed some light on the problem, however.

Conclusion

Wastes will continue to enter fresh-water aquifers in the future as they have in the past. The anticipated growth in population, industry, and technology will produce vastly greater quantities and new types of waste. The most obvious method of protection of the aquifers is treatment of the waste at its source; however, complete treatment may be out of economic reach. Intentional recharge with some types of waste will certainly be continued.

In order to meet the challenge of the next few decades, a substantial amount of research and field investigation will be needed in the geologic, hydrologic, chemical, physical, and geophysical phases of the problem. Water and waste management programs cannot be successful unless tools are provided to do the job.

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Federal Research and Development Program for Saline-Water Conversion

Allen Cywin and Lewis S. Finch

A paper presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla., by Allen Cywin, Asst. Director for Demonstration Plants, Office of Saline Water, Dept. of the Interior, Washington, D.C., and Lewis S. Finch, Member of Site Committee, Vice-Pres. & Chief Engr., Indianapolis Water Co., Indianapolis, Ind.

ALTHOUGH the possibility of converting saline water to fresh water has only recently gained widespread interest, the idea is no by means new. As early as 1593, an English sea captain, Sir Richard Hawkins, wrote [1]:

> Although our fresh water has failed us many days, . . . yet with an invention I had in my shippe I easily drew out of the water of the Sea sufficient quantities of Fresh Water to sustain my people with little expense of fewell; for with foure billets I stilled a hogshead of water, and therewith dressed the meat for the sick and the whole. The water so distilled we found to be wholesome and nourishing.

Unfortunately, information on the experiences of Hawkins and others was not adequately disseminated among mariners for many years. After making his own investigation, Thomas Jefferson, in 1791, expressly recommended that knowledge about sea water distillation be made available to all mariners in the first official scientific document published by the United States Government. The recommendation was not adopted, however. Ships continued to run short of water in a field of plenty.

It was with the advent of steam power that sea water conversion slowly began to be adopted, although still largely for maritime purposes. Through the Nineteenth Century, controversies raged about the potability of distilled water, discouraging its universal acceptance. It was not until World War II, when ships were forced to operate for long periods at sea and armed forces had to become self-sufficient on beachheads and deserts, that real attention was turned toward exploiting the potentialities of sea water conversion. Only rarely was saline-water conversion ever resorted to for civilian applications, except for fields with a high-purity requirement, such as for boiler feedwater or pharmaceutical water.

Need for Additional Sources

More recently, however, the general public has become increasingly aware of domestic water supply problems—of both quantity and quality—which in many areas cannot be adequately met by available conventional resources.

At the same time, the national consumption of fresh water is growing at an accelerating pace, along with rapid increases in population, industry, and agriculture. Recent estimates forecast a doubling of the national demand for fresh water by 1980.

A part of this new demand will have to be met from the readily accessible but as yet untapped sources of brackish or sea waters contiguous to or underlying most of the major water-short areas. This fact was realized soon after the end of World War II, but saline-water conversion systems available at that time produced water that was very expensive by the standards for fresh water. In addition, commercial enterprises were reluctant to try new processes or techniques because of the expense and risks involved. New and more economical methods, therefore, had to be developed in order to utilize saline-water resources.

Saline-Water Program

In 1950, President Truman wrote to the heads of several government departments and directed that studies be initiated toward determining the possibility of utilizing saline water as a potential source of future water supply. This resulted in the first Saline Water Act passed by Congress in July 1952. That act authorized the expenditure of no more than $2,000,000 for a 5-year exploratory research program and further stated:

> In view of the acute water shortage in arid areas of the nation and elsewhere and the excessive use of underground waters throughout the nation, it is the policy of the Congress to provide for the development of practicable low-cost means of producing from sea water, or from other saline waters, water of a quality suitable for agriculture, industrial, and other beneficial consumptive uses on a scale sufficient to determine the feasibility of the development of such production and distribution on a large-scale basis, for the purpose of conserving and increasing the water resources of the nation.

The law was amended in 1955 to extend the research and development program over a 10-year period at a total expenditure not to exceed $10,000,000. The federal saline-water conversion research and development program is being administered by the Office of Saline Water of the Department of the Interior. In administering this program, the Office of Saline Water has encouraged educational institutions and private industry to participate in the research and development work. In fact, most of the federal research projects have been carried out either by educational institutions or by private industry operating under contract with the Department of the Interior. Thus the government program has helped in the development of an infant saline-water conversion industry.

This cooperative program, together with the developing water shortages, has spurred national and international interest in improving existing methods and developing new techniques for saline-water conversion. So great has been this interest that the modest government program has been substantially augmented by the contributions and independent research programs of private industry. This, in turn, has led to the development of improved civilian saline-water plants, which are now being installed in increasingly large sizes in more and more places throughout the world. The largest electrodialysis installation, located in South Africa, has a capacity of 2.8 mgd, but, for the most part, distillation units have had the largest installed capacity, the largest unit being in Kuwait (Persian Gulf) with a capacity of 6.75 mgd. Several multimillion-gallon-per-day plants also are being actively considered. Understandably, because of

the investment involved and the need for guaranteed water production, existing installations have not taken maximum advantage of some of the new techniques and processes which promise a relatively low-cost production. Thus far, saline-water conversion processes fall into five general categories: distillation, membrane, freezing, chemical, and others.

Distillation Processes

Distillation, or evaporation, was until very recently the only truly commercial method for demineralizing saline water. In its simplest form, distillation is that process whereby water is caused to boil and form steam, the steam then being caused to condense back into liquid.[2] Today, distillation apparatus is widely used—not only to supply fresh water for marine and military service, but also for the high-purity requirements for industrial, pharmaceutical, and process water uses. In addition, sea water evaporators are being increasingly used for domestic and limited industrial use in scattered regions of the world, more than 90 per cent of the present total capacity having been installed in the last few years. There are thus several distinctly different types of sea water evaporators and, of course, combination systems. The distillation processes most highly developed and showing the most promise for use at the present time are described briefly below:

Vapor compression distillation. This process is an application of the heat pump. Vapor from an evaporator is compressed until its temperature is about 10°F and higher than when originally formed. Then it is returned to the evaporator, where it condenses into water. In so doing, it gives up heat in sufficient amounts to evaporate more water. The input energy is mechanical (power to drive the compressor) rather than thermal.

Multiple-effect distillation. Several boiling chambers, or "effects," are used to achieve greater efficiency of heat utilization. Steam from a boiler evaporates part of the sea water in the first effect. The vapor from the first effect moves to the next effect where it passes on its heat, causing evaporation of brine in the second effect. This process is repeated through several effects. The greater the number of effects, the greater is the economy of heat utilization. Each successive effect evaporates less water than the previous one, however, and the capital cost of added effects must, therefore, be balanced against the value of the additional water produced.

Flash evaporation. Water under low pressure will boil at a correspondingly lower temperature. Thus, if warm salt water (near the boiling point) is enclosed in a chamber and the pressure is lowered below the boiling pressure of the salt water, part of the water will "flash" to vapor, which then can be condensed into pure water. The warmer the water and the greater the reduction in pressure, the greater will be the evaporation.

Scaling (precipitation of salts such as $CaCO_3$, $MgOH_2$, and $CaSO_4$) and corrosion are the great deterrents to the production of lower-cost water by distillation processes. New techniques and feedwater treatments under development are, however, slowly, but surely, removing these problems. Evaporators are used for all types of saline waters but are usually most economical (compared to other processes) on waters of greater salinity.

Membrane Processes

Whereas the distillation process removes the fresh water (96.5 per cent of sea water) from the salt water body, a membrane type of demineralizing technique involves the removal of the salt (3.5 per cent of sea water) from the saline source of supply. This is called ion-transfer and the membranes are used either as filters for ion migration, preventing water flow, or as barriers to ion movement, permitting water flow. Three types of membrane processes are described below.

Electrodialysis. The leading and only commercial membrane process is known as electrodialysis. Although its principles were known for many years, practical applications had to await the development of suitable membranes. Even though such membranes were developed and were first put to use just 10 years ago, the present economic potential for electrodialysis is in the conversion of brackish water, rather than sea water, as many brackish waters have a far lower salt content than sea water.

In the electrodialysis process, ion-permeable membranes are interposed in a bath of saline water. Alternate membranes allow only cations (Na^+) or anions (Cl^-) to pass under the influence of an electromotive force, thereby demineralizing the water in every other compartment. New membrane and hydraulic developments are improving the efficiency and cost potential of this process, and the growing number of equipment applications is providing good experience in water pretreatment and scale prevention for this process.

Reverse osmosis. Another type of membrane, which permits water rather than salt to flow and utilizes pressures rather than an electrical force, is used in osmotic processes. Normally, osmosis involves the passage of water, through a membrane, from a dilute solution into a more concentrated one, or, in other words, from the fresh-water side into the salt water. This, of course, is the very reverse of the desired direction of flow. To reverse the direction of flow, the saline concentrate must be at a much higher pressure than the fresh water. For sea water, 350 psi is needed to overcome its normal osmotic pressure differential with fresh water.

Osmotic-ionic process. A third type of membrane process utilizes a combination of osmotic and ionic forces. In its simplest form, two cation-selective membranes and two anion-selective membranes form a three-compartment cell, each chamber initially containing feedwater and the entire unit being immersed in brine. The passage of ions from the brine to the less highly concentrated water in the outer chamber is necessarily electrostatically coupled with simultaneous transfer of ions from the center to the outer chamber, thereby demineralizing the center chamber. This is a brand-new concept still in its initial development stages.

Freezing Processes

The present "dark horse" among the conversion processes is the freeze-demineralization process—that is, separating fresh-water ice crystals from the saline water. Compared to other processes, freezing has certain inherent advantages, such as lesser tendency toward scaling and corrosion and the ability to operate with less thermal interchange.

Freezing the fresh-water crystals out of the saline water is only one stage in

the separation process, however. Unfortunately, ice frozen from saline solutions occludes or entraps brine in the interstices of the crystallite forms and a solid-liquid phase separation thus becomes necessary.

There are at present two freezing methods with a good potential for economically producing ice from sea water: freeze-evaporation and direct refrigerant cooling.

The very first freezing pilot plant of any size (15,000 gpd), was designed and is under test by the Carrier Corporation. In this plant, synthetic sea water is introduced into a high-vacuum chamber and is flash-cooled to a temperature low enough to produce ice crystals. The water vapor is an additional source of purified water and is either mechanically evacuated from the freezing chamber or handled by an absorption unit. In either case, large volume devices are needed to handle the low-pressure water vapor. The ice crystals are washed free of the brine in a countercurrent wash chamber. The pilot plant installation is to be rebuilt this summer at Harbor Island, Wrightsville, N.C., under contract with the Office of Saline Water to test the method on actual sea water.

In the other leading freezing process, a refrigerant such as isobutane is introduced directly into the brine, thus freezing some of the solution into ice crystals. The freezing chamber and wash column may be separated or combined. The use of a direct refrigerant greatly reduces the size of compressor needed but adds the complication of having to handle a second fluid with little or no loss. A pilot plant of 35,000 gpd is now being designed by the Blaw-Knox Co. for the Office of Saline Water. This plant, which will be located near St. Petersburg, Fla., will be under construction this summer.

Chemical Processes

Chemicals can be used to remove water molecules from a salt water solution. Two such processes being actively investigated are known as solvent extraction and gas hydrate separation techniques.

Solvent extraction. In this process, the solvent must first selectively dissolve appreciable quantities of water from the saline solution, leaving the brine behind. Secondly, the solvent must, under a temperature increment, undergo a phase change (vaporization), thereby releasing the water molecules previously dissolved. Finally, the solubility of water in the solvent must be much greater than that of the solvent in water, or the cost of recovering the solvent would be prohibitive. This process is theoretically applicable to brackish waters, but suitable solvents are still to be developed.

Gas hydrate separation. This process consists of contacting salt water with certain gases, such as light hydrocarbons or halogenated methanes, to form a solid crystalline hydrate. The mother liquor then is washed or otherwise separated from the crystals, and fresh water is obtained by melting the hydrate. Very recent laboratory studies lead to some optimism for this new process. A pilot plant appears necessary to establish a method of avoiding the difficulty in holding the hydrocarbon loss to a bare minimum while large quantities of fresh water are being produced.

Demonstration Plant Program

Encouraged by the promise of ultimate economic results, Congress passed the Saline Water Demonstration Plant

Act, signed by President Eisenhower on Sep. 2, 1958, to "transform experiments into production tests on a scale not possible of achievement otherwise." After a careful study, Secretary of the Interior Fred A. Seaton assigned the responsibility for the demonstration program to the Office of Saline Water, now under the direction of Arthur L. Miller.

The act provides for the construction, on the West, East, and Gulf coasts, of at least three sea water conversion plants, two of 1,000,000 gpd capacity each. Two demonstration plants for the conversion of brackish water, one of which is to be at least 250,000 gpd in capacity, have been authorized. One is to be located in the northern Great Plains region, and the other in the arid areas of the Southwest. The act further provides that "such plants shall be designed to demonstrate the reliability, engineering, operating, and economic potentials of the sea or brackish-water conversion processes which the Secretary [of the Interior] shall select from among the most promising of the presently known processes, and each plant shall demonstrate a different process." Compared with sea water, brackish water has a lesser degree of salinity.

Process Selection

Because of the many commercial processes and research and development programs, a special Process Selection Board was appointed by Assistant Secretary of the Interior Fred G. Aandahl to assist in appraising and recommending demonstration processes from among those available. The Process Selection Board consists of Ralph A. Morgan, president of Rose Polytechnic Institute; Dudley Phelps, president of the J. G. White Engineering Corporation; and Captain Ivan Monk, of the Navy Bureau of Ships. From criteria established by that board and upon its recommendation, five of the most advanced and potentially promising processes have been selected for demonstration. These are:

1. Multiple-effect long-tube vertical distillation (1,000,000 gpd)
2. Multistage flash distillation (1,000,000 gpd)
3. Electrodialysis (not further defined) (250,000 gpd)
4. Forced-circulation vapor compression distillation (250,000 gpd)
5. Freezing (not further defined) (100,000 to 350,000 gpd).

Site Selection

Wide national interest in the saline-water program was engendered with the announcement of the new demonstration program. Since passage of the Demonstration Plant Act, nearly 200 communities from every coastal state and many inland states have asked to be considered for one of the five plants, most of them offering more than one site. With the number of communities pleading for consideration and the variations in processes for each region, selection was very difficult.

In view of the difficulties, Secretary of the Interior Seaton authorized the appointment of an independent three-man board to assist him in the selection of sites in each area which might adequately serve to demonstrate each of the selected processes. The board members are Sheppard T. Powell, of Sheppard T. Powell & Assocs., Baltimore, Md.; W. C. Schroeder, of the University of Maryland; and Lewis S. Finch, vice-president and chief engineer of Indianapolis (Ind.) Water Co.

At its first meeting, the site selection board was presented with information gathered by the Office of Saline Water through a questionnaire submitted to each community applying and followed up by a personal visit and report wherever possible. State officials have been most helpful both in this preliminary phase and throughout the selection procedures.

The site selection board, recognizing the inherent difficulties involved in the making of decisions based upon a general review of such a mass of data, established a two-step procedure of engineering evaluation. Under this plan, each community is given equal consideration and applications and new information are reviewed right up to the drafting of the final recommendations for each area.

The first step is a screening of all proposed sites in a particular area to determine whether any of certain disqualifying factors previously established by the board apply to the site under study. If one or more of these disqualifying factors apply to a site under study, it is eliminated from further consideration. Typical disqualifying factors for one area might be:

1. An adequate existing fresh-water supply already available
2. A water requirement and system too small to consume the water produced by a conversion plant
3. A seriously contaminated saline-water source
4. A lack of available means for economical disposal of brine
5. Hazardous design and operation conditions imposed by environmental, topographic, or weather conditions
6. Prohibitive cost of reaching a proper saline- or brackish-water supply
7. Failure of site to meet the requirements of Public Law 85-883
8. Inaccessibility of the site
9. Quantitative or qualitative inadequacy of the raw-water supply
10. Miscellaneous disqualifying conditions.

The second step is an evaluation of the remaining sites in accordance with a 1,000-point rating schedule. The rating schedule is a uniform scoring system devised by the board for comparing the merits of each site in a particular region. Evaluating factors are broken down into three major headings: technical factors (62 per cent); demonstration value (24 per cent); and assistance offered (14 per cent). With a potential 1,000-point total score, various subfactors are further rated on the basis of a potential 20-, 40-, 60-, or 100-point value, depending upon the relative importance of the particular factor. Subfactors for each site then are compared to those of other competitive sites, based upon the best engineering judgment of the board. After screening and preliminary grading, a group of the very best sites is chosen for personal inspection by the board. Following this final site inspection, the board rescreens and regrades the remaining candidates. Final recommendations are made to the Secretary of the Interior in a formal report, in which the relative merits of all acceptable sites are compared in detail.

As a result of the painstaking procedure described above, four sites have been selected to date by the Secretary of the Interior from among those which the board has indicated to be acceptable. The process of selecting the fifth (East Coast) site is in progress, the board having completed the screening of all of the sites that have been proposed to date.

The selected sites are:

1. Freeport, Tex., for the 1,000,000-gpd long-tube vertical distillation process
2. Originally, a site at San Diego, Calif. (Point Loma), for a 1,000,000-gpd multistage flash distillation process conversion plant
3. Webster, S.D., for a 250,000-gpd electrodialysis plant
4. Roswell, N.M., for a 250,000-gpd forced-circulation vapor-compression demonstration plant
5. Somewhere on the East Coast for a freezing process. (More than 40 community applications, from every Atlantic state, currently are being studied for this selection.)

Construction Program

Present plans call for the completion of the first three plants in the fiscal year 1961 and the last two in the fiscal year 1962. Plans and specifications for the first plant at Freeport, Tex., were issued to interested parties on Apr. 1, 1960. More than 200 sets of plans and specifications were taken out by contractors, equipment manufacturers, and other interested parties. Bids were scheduled to be opened on May 24, 1960.* The Southern California plans and design specifications and the Webster, S.D., specifications were to be issued to potential bidders in July 1960.

By law, the plants are to be operated under contract with the federal government until Sep. 2, 1965. They then are to be sold to the highest bidder, or as Congress may otherwise direct. It is hoped that the knowledge and experience gained from this activity will bring the nation closer to its goal of achieving economical saline-water conversion.

Water Costs

No other utility service affects each citizen more vitally every day and is taken more for granted than water. Yet the consuming public, for the most part, is reluctant to pay the rates needed to secure modernization and extension of water service. In comparison with the rates paid for telephone service or for electricity and gas, water rates are almost unbelievably low. If water rates are not adequate to support the facilities necessary to provide an abundant and satisfactory water supply, they are "penny-wise and pound-foolish," [3] for, when it is in short supply, water is priceless.

It is well to remember also that, although water is priceless because it is indispensable, the price paid by the customer may be thought of in terms of water *value*, water *cost*, or water *rates*. The water supply industry is faced with the difficult problem of placing each of these terms in its proper perspective. It must persuade the public to authorize new bond issues and to pay higher rates often for doing nothing more than replacing wornout facilities. When existing facilities also must be extended or supplemented, the problem becomes quite serious.

Water from any source of supply should be priced according to the cost of its production (reflecting quality as well as quantity and delivery), including proper depreciation charges for the replacement of the facilities at the end of their useful life, as well as the cost of amortization. Saline-water conversion costs are calculated by the Office of Saline Water in accordance with a rigid standard procedure which gives recognition to such items as engineering, maintenance and operation, depre-

* Since the time of writing, the contract was awarded to Chicago Bridge & Iron Co., Chicago, Ill.

ciation, insurance, taxes, total plant investment, and amortization.[3] Converted water must meet the USPHS Drinking Water Standards and contain no more than 500 ppm total dissolved solids. This pricing procedure was devised to compare one process with another and not to compare process costs with water costs or rates computed on a different basis. In 1952, the costs of saline-water conversion, when computed by that procedure, amounted to $4–$5 per 1,000 gal. Those costs were high partly because the plants were small and also because the equipment was designed primarily for marine service. Now that a market for civilian equipment is developing, the individual plant size and efficiency of operation have improved, and a realistic present-day cost of conversion is less than $2 per 1,000 gal for presently installed plants.

Saline water plants now under construction and being designed should be capable of producing water at close to $1 per 1,000 gal in plant sizes of approximately 1 mgd. When one considers the inflationary period of the 1950's, one truly must be proud of the 400 per cent improvement in process costs in the past decade.

Without any further improvement in technology, these same commercial processes should be capable of lower-cost water production in plants of larger sizes. Combination of these processes with brackish-water blending, process steam production, power production, and salt or chemical operations, can further reduce the cost properly attributable to saline-water conversion. Also, it should be realized that present research and development programs are providing new information to help in improving processes and techniques and in lowering the cost of conversion. In fact, it is not completely unrealistic to predict a future total production cost, including amortization, of 50 cents or less per 1,000 gal.

Furthermore, in comparing the cost of converted water with that of conventionally produced water, one must not accept the stated cost of the conventionally produced water as including all of the cost involved, unless it definitely is determined that recognition has been given to all of the cost items cited above and that allowance has been made for money derived from taxation or assessments.

Some communities in the United States today pay $5–$7 per 1,000 gal for hauled water. As a portent of things to come, one of these communities, Coalinga, Calif., recently purchased a small electrodialysis demineralizer and thus has become the first American municipality to utilize saline water, brackish ground water in this instance, for domestic supply.

Other communities and individual water-consuming industries are finding that the cost of new supplies, although not as high as the above, are rapidly approaching the point where the alternative of saline-water conversion is well worth careful consideration. Converted water is a potentially reliable and plentiful source of supply in certain areas where adequate supplies of fresh water cannot be obtained except at a prohibitive cost. Certainly, a community with a plentiful supply of converted saline water is better able to furnish an adequate supply to its citizens and to face emergencies than is a community which depends solely upon a source of supply which is subject to disruption or severe drought.

Conversion systems also have a certain flexibility, in that they can be installed (as can conventional plants) meet the demands of the immediate in increments of size as necessary to

future, whereas major diversions or water impoundment projects must of necessity be built of a size to meet the water needs of the community for many years to come.

Conclusion

The potential applications for saline-water conversion processes are many. Saline water conversion can, of course, have a profound effect on mankind all over the world, and the results can be only beneficial.

The problem of cost reduction, for producing this most valuable commodity, loses some of its present significance as our burgeoning population reaches farther and farther out for new water supplies and as the cost comparisons are reduced to common denominators.

Just when the large conversion plants of the future will be producing is difficult to foretell. Nearly 20 mil gal of fresh water are being produced from saline water each day. Although small in the terms of the larger city and industrial requirements, this represents a fifteen-fold increase in the past decade. New processes to be demonstrated shortly and those still under development will help to accelerate progress as the public is made increasingly aware of the full potentials of saline-water conversion as a supplemental or alternative source of high-quality fresh-water supply.

A number of communities in the northern Great Plains and in the arid regions of the Southwest presently have no available public water supplies and must depend upon backyard wells or bottled water for drinking purposes. Along each of the seacoasts, there are cities and towns which either now are or soon will be faced with the problem of inadequate fresh-water supplies or supplies that are subject to sea water intrusion. For such communities, a saline-water conversion plant will solve the water supply problem—and at costs that are not prohibitive, for water is a "priceless commodity."

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Improved Solar Still Process for Desalting Sea and Brackish Waters

Werner N. Grune and Iraj Zandi

A contribution to the Journal by Werner N. Grune, Prof. of Civ. Eng., and Iraj Zandi, Graduate Research Asst., both of the San. Eng. Research Labs., School of Civ. Eng., Georgia Institute of Technology, Atlanta, Ga. *The investigation (Project E-180) was supported by a grant from the Eng. Experiment Sta., Georgia Institute of Technology. The article is based on a thesis approved in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the School of Civ. Eng., Georgia Institute of Technology, Oct. 29, 1959.*

THE earth and its atmosphere hold an immense store of water in an everlasting equilibrium that cannot be changed. With the exception of a minute fraction, all of the world's water is in the oceans, but this water has accumulated salt for millions of years and is thus useless for most of man's needs. Nature has provided ample resources of water, but nature's timing of delivery and distribution of water are imperfectly suited for man. Rainfall in the United States varies from the lush abundance in the evergreen Pacific Northwest to the scarcity in the parched Southwest. Furthermore, in any one region the recorded total precipitation varies widely from season to season and from year to year. Neither water nor the demand for it is evenly distributed.

Howe[1-3] has aptly discussed the conversion of sea water to fresh water to support life in plants and animals and the early efforts of man to bring about such a conversion. His presentation[1] includes the composition of sea water in terms of ion concentrations, demineralization processes according to their energy requirements, the costs of water, multiple-effect flash distillation, critical and supercritical pressure distillation, vapor compression distillation, vacuum flash distillation with the use of the low-temperature-difference power plant, and solar distillation. The discussion is presented in chronologic sequence and includes 307 references. In addition to the methods discussed by Howe, freezing processes, chemical processes, electrical methods, membrane methods, and other techniques have been discussed by others. This article is devoted only to the application of solar energy for the demineralization of salt and brackish waters.

Many arid regions of the world have experienced scarcity of water. Generally, the shortage of fresh water is more critical where an abundance of the sun's energy is available. Utilization of the unlimited, free energy of the sun to convert undesirable sea water or inland brackish water to fresh and desirable water appears immediately attractive. Solar energy may be successfully harnessed to furnish fresh water from saline water at a cost competitive with conventional supplies in

certain locations. Theoretically, the available supply of solar energy far exceeds the need. Solar energy, however, is only available in the form of low-temperature heat, which, by the second law of thermodynamics, is difficult to convert economically into work and is difficult to store or to transport. Because of the difference in wavelength between solar radiation and thermal radiation from a heated body, it is possible to construct an energy trap and permit the short-wave solar radiation to enter the trap, which may be made opaque to the long-wave thermal radiation emanating from the collector plate. The collected energy can then be utilized advantageously to distilled sea water or brackish water.

A conventional solar still, although simple in design and operation, produces only a small amount of water per unit of area. The low efficiency is the result of the dispersed form of solar energy and also an inherent property of the still design. A conventional solar still combines three processes in one unit: collection of solar energy, evaporation, and condensation. It relies on natural convection within the still and the cooling effect of ambient air. Large areas for the solar still and a considerable amount of equipment and glass are required for

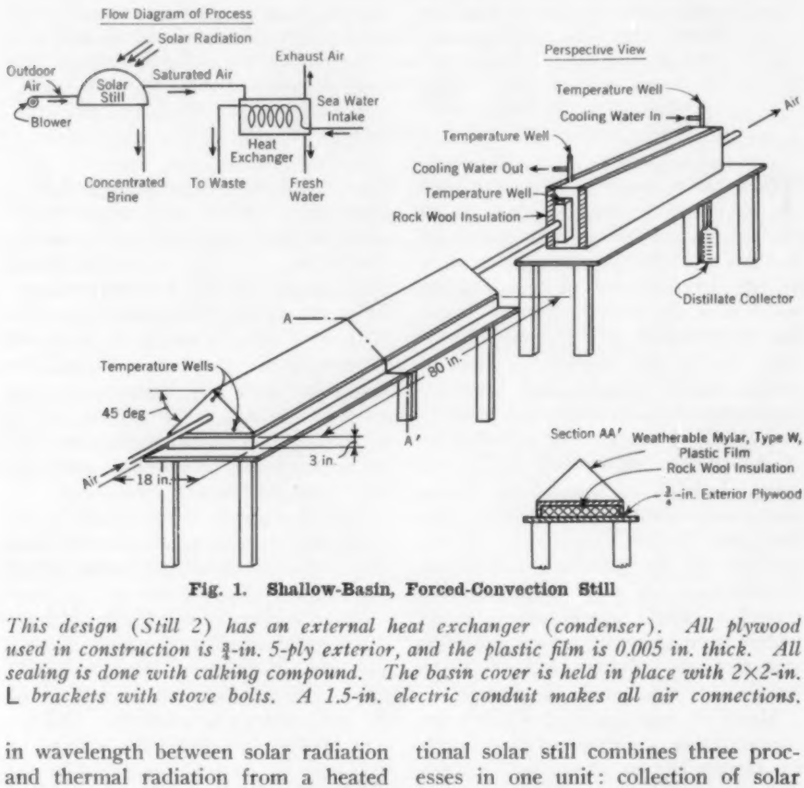

Fig. 1. Shallow-Basin, Forced-Convection Still

This design (Still 2) has an external heat exchanger (condenser). All plywood used in construction is ¾-in. 5-ply exterior, and the plastic film is 0.005 in. thick. All sealing is done with calking compound. The basin cover is held in place with 2×2-in. L brackets with stove bolts. A 1.5-in. electric conduit makes all air connections.

the utilization of solar energy; therefore, costs are high.

New Design Features

Several new design features have been investigated to improve the yield of existing solar stills. One of the improvements is the mechanical separation of the collector-evaporator unit from the condenser. A further improvement is the use of air as an intermediate substance that substitutes forced convection for natural convection to increase evaporation. In addition, this design utilizes droplet evaporation in lieu of flat-sheet evaporation to increase the interfacial area between carrier and water droplet.

Another important feature of the new design is the reuse of energy in an external heat exchanger to preheat the incoming sea water while the condensate is extracted from the saturated vapor. The cooled and dewatered air can be recycled to the still.

The improved design uses forced air as an intermediate substance that speeds up the heat and mass interchanges necessary for rapid and economical solar distillation. Within the still, the air comes into intimate contact with a shower or spray of preheated sea water. In an external heat exchanger, the saturated air preheats the incoming sea water and simultaneously causes the vapor to condense as fresh water. To recover the water content of the saturated air, which is at the temperature of the still, thermodynamic considerations dictate the passage of nearly twenty times the condensate volume of cold sea water through the heat exchanger, attended by a temperature rise of the sea water. A part of this large volume of sea water, at a relatively high temperature, is stored in the deep-basin still and, in this way, provides for the continuous production of fresh water. Whereas droplet evaporation provides for daytime production, during the remaining portion of the 24-hr period conversion is based on the deep-basin principle.[4]

A plastic film * provides a simple, lightweight collector-evaporator unit. A complete lack of collecting troughs further simplifies the design, construction, operation, and maintenance of the shallow-basin, forced-convection still.

Experimental Stills

The experimental plant was located on the roof of the Chemistry Annex Building on the Georgia Institute of Technology campus, Atlanta, Ga., at a latitude of 33°46′45″. Collection of preliminary data was begun in March 1959. The equipment was tested and improved until May 19, when reliable data collection was started and carried through until the end of September 1959.

Four experimental stills of different designs, each 9 sq ft in cross-sectional area, with plastic film canopies, were evaluated. The main characteristics of the four experimental designs are:

1. Still 1, deep basin (natural convection). The principal differences from the conventional design are a considerably deeper layer of water in the basin (44 gal, instead of 9 gal) and a plastic film canopy.

2. Still 2, shallow basin (forced convection). Air is employed as an intermediate substance to speed up the heat and mass transfer for rapid and economical solar distillation. The still utilizes an external condenser (Fig. 1).

* Mylar, Type W (Weatherable Mylar), a product of E. I. du Pont de Nemours & Co., Wilmington, Del., developed especially for greenhouses and solar stills.

3. Still 3, shallow basin (natural convection). This still differs from the conventional design insofar as the canopy consists of a plastic film instead of glass.

4. Still 4, deep basin (forced convection). Two variations of this design were investigated: one without any spray and another with an intermediate tray for the dispersion of water in the form of droplets (Fig. 2).

For purposes of comparison, a conventional still, with shallow basin and glass canopy, was constructed and investigated along with the four experimental designs. The conventional still was designated as Still 5. Figure 3 shows the experimental setup with all five stills and associated equipment on the roof of the Chemistry Annex Building.

Experimental Procedure

As soon as the construction of stills was complete, experimental data were collected for each still during the fol-

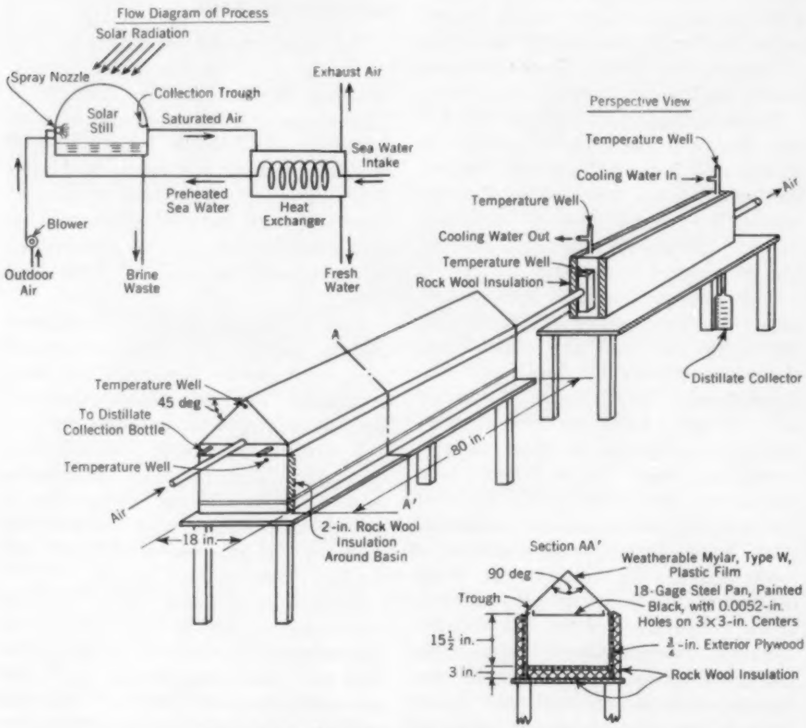

Fig. 2. Deep-Basin, Forced-Convection Still

The same materials are used in this still (Still 4) as in Still 2—namely, $\frac{3}{4}$-in. 5-ply exterior plywood, 0.005-in. thick plastic film, calking compound for sealing, and 2×2-in. L *brackets with stove bolts to hold the basin cover in place. The still has an external heat exchanger.*

lowing time periods: Stills 1, 2, and 3, May 19–Sep. 30, 1959; Still 4, prior to insulation and operating with forced convection, Jun. 11–Aug. 15, 1959; insulated, but without forced convection, Aug. 15–25, 1959; and with forced convection and with external heat exchanger, Aug. 25–Sep. 30, 1959. Still 5 was operated during Jul. 24–Sep. 30, 1959. These data collections were continued until Aug. 25, 1959, on an average of four times daily, with one of the readings taken early in the morning and the other late in the afternoon. After Aug. 25, 1959, readings were collected on an hourly basis, from 7 or 8 AM to 5 PM, and continued every other hour until 11 PM. This program of reading was continued until Sep. 30, 1959.

Readings from 7 or 8 AM to 7 PM were assumed to constitute the daytime production from solar energy for that day. Data from 7 PM to 7 or 8 AM the next morning were considered nighttime production for the same day. Total production is the sum of these two values.

As in any solar still system there are a number of uncontrollable variables that affect its operation, the known variables were eliminated as far as possible. To eliminate the effect due to geometric proportions, it was decided to construct and design all experimental stills of equal size. This provision permitted direct and reliable comparisons. Another important factor considered to affect the operation is the quantity of water stored in the stills. All shallow basins, therefore, were designed to have the same capacity as all deep basins. As many as 9 gal of water were maintained within the shallow basin stills during experimentation. The deep basins could accommodate 44 gal. Generally, water was added each morning to maintain the same volume inside the stills. To reproduce the same volume from day to day, control was maintained by means of a water level indicator.

Tap water instead of salt water was used in these experiments. Such use is permissible and does not affect the theoretic evaluation of processes, be-

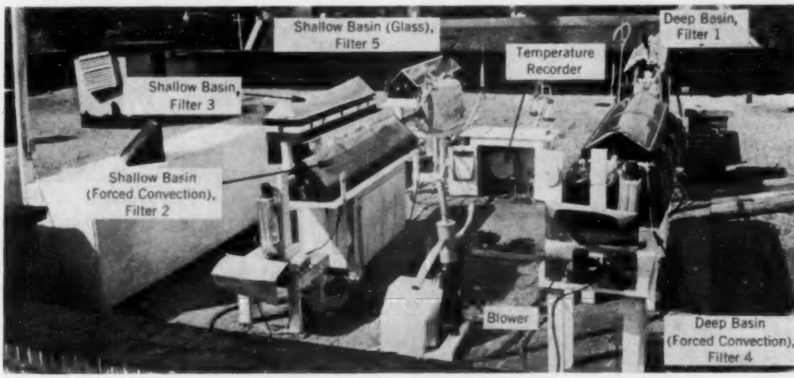

Fig. 3. Experimental Setup, All Stills

All five stills were set up on the roof of the Chemistry Annex Building at the Georgia Institute of Technology.

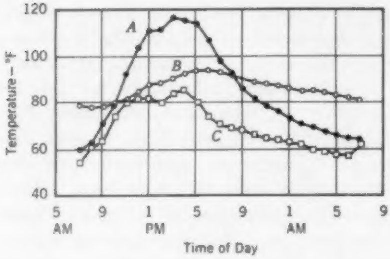

Fig. 4. Temperature Variation in Shallow and Deep Basins

Curve A *represents the temperature in the shallow basin (Still 3);* B, *the temperature in the insulated deep basin (Still 1); and* C, *the outside temperature in the shade. The data were recorded on Sep. 21, 1959, a typical day during the study period.*

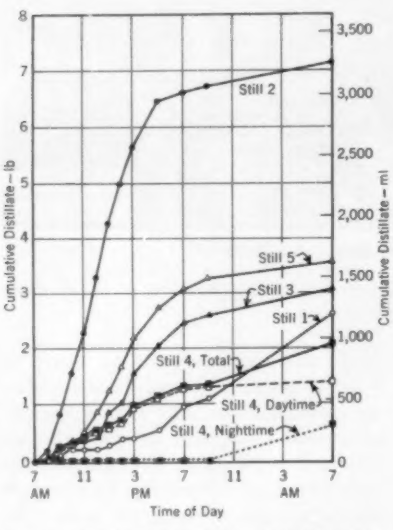

Fig. 5. Typical Cumulative Daily Production From All Stills—Aug. 27, 1959

Production of distillate depends on the difference in temperature between water and transparent material or between water and air in the still.

cause the vapor pressure of sea water with a salt content of 30,000 ppm is only slightly less than that of fresh water,[3] except when corrosion and scale formation are involved. To compare the operation of the experimental stills with the conventional shallow-basin design, it is desirable to study the operational data from each still separately.

Deep Basin (Natural Convection)

With natural convection and the cooling effect of ambient air, fresh-water production is a function of the difference between the temperature of the water and that of the transparent material, which is closely related to ambient temperature. When this temperature difference increases, distillation increases; when the temperature difference decreases, distillation decreases. The hourly variation of temperature inside the insulated deep basin (Still 1) and the ambient temperature for a typical day (Sep. 21, 1959) are shown in Fig. 4. It will be noted that until 6 AM the difference between ambient air temperature (outside) and water temperature (inside) is considerable. After the sun rises, the temperature difference decreases. Approximately at noon, the difference reaches its minimum. At 2 PM a drop in ambient temperature due to heavy cloud formations is observed. The effect on the water temperature is much less pronounced, because water has a higher heat capacity than air. After 2 PM the air temperature again rises, as does the water temperature. After 4 PM the air temperature declines for the day, while the water temperature in the still rises for another 1.5 hr and then drops off, but at a much slower rate than the drop in air temperature. The slower cool-

ing of the water results from the fact that the basin is insulated and contains a large volume of water. Although the value of the sun's energy declines, the incoming heat still exceeds the small losses from the insulated deep basin. The water temperature is generally not more than 20°F higher than the ambient temperature during the maximum temperature differential period, which usually occurs 6–8 hr after the period of greatest insolation. As the night progresses, the temperature difference continues to increase. On the basis of these variations, it is to be expected that in the morning, from 7 AM to 9 AM, more water will be produced than from 9 AM to 5 PM. Nighttime production will be considerably greater than production during daylight hours. The validity of this deduction is apparent from the data in Table 1.

TABLE 1

*Hourly Distillate From Deep-Basin Still, Sep. 21, 1959**

Time	Distillate *ml*
8–9 AM	100
9–10 AM	20
10–11 AM	30
11–12 AM	40
12–1 PM	10
1–2 PM	0
2–3 PM	10
3–4 PM	25
4–5 PM	15
5–7 PM	50
7–9 PM	175
9–11 PM	250
11 PM–8 AM	525

* Still 4 is operated on the forced-convection principle; therefore, distillate production during the day is from the heat exchanger. The differences in production for Still 1 on Aug. 28, 1959 (Fig. 6), and the data for Sep. 21, 1959, are most likely the result of antecedent, ambient temperatures (during the previous night), causing differences in condenser surface efficiency.

On Aug. 27, 1959, Still 1 (deep basin, natural convection) produced during the night approximately 160 per cent more distillate than that produced during daylight hours (Fig. 5). This behavior is typical for the deep-basin still. Actually, production depends on the difference of temperature between water and transparent material. During daylight hours, the transparent material has a higher temperature than the ambient air, because transparent materials are exposed directly to, and absorb a portion of, solar radiation; but the ambient temperature is measured in the shade.

The results confirm the fact that yield increases as the total daily solar energy increases. A plot of the distillate from the deep-basin still against solar energy showed a definite upward trend. The line of best fit for these data by the method of least squares showed a coefficient of linear correlation of 0.53. The equation of best fit, found by linear regression, is:

$$q_f = 0.089 + 0.117H$$

in which q_f is the distillate in pounds per square foot per day, and H is the total solar energy available in 1,000 Btu/sq ft/day.

It has already been pointed out that the daytime production is very small. It was also shown in Table 1 that the point of smallest production is approximately at noon. This is the time of maximum solar intensity. Therefore, it appears that there may exist an inverse relationship between daytime production and total solar energy available. But it was found that, for all practical purposes, daytime production is independent of solar energy for values of 800–2,500 Btu/sq ft/day.

To study the effect of insulation on the operation of the deep-basin design, the collector-evaporator unit of Still 4 (deep basin, forced convection) was placed into operation as a control prior

to its insulation and the forcing of air through it. Since both the control unit and the regular unit were identical, any difference in operation was attributed to the effect of insulation. Results indicated that the noninsulated deep basin operated at a higher tempera-

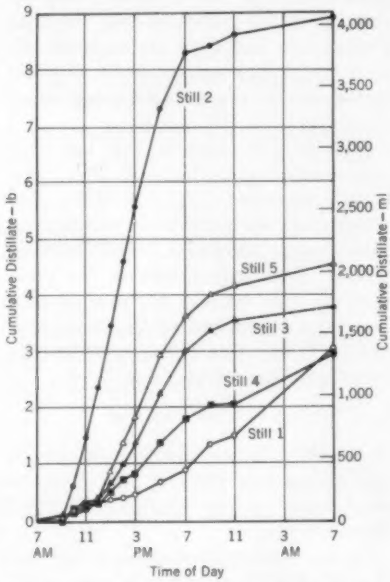

Fig. 6. Typical Cumulative Daily Production From All Stills—Aug. 28, 1959

Production is slow early in the day because of the time required for the cold water to heat up. The greater rate of production starts at approximately noon, but Still 1 (deep basin) produces best during the night.

ture. It was observed that both the cooling down and heating up of the noninsulated still occurred faster.

Shallow Basin (Glass)

Data available in the literature on the distillate production from a conventional still (Still 5) are so varied that no realistic comparison was possible. It was therefore decided to test this still along with the other designs. The inconsistency of data reported is readily understandable in view of the many uncontrollable factors involved. Generally, the behavior of this design was found to conform with the reports cited in the literature. Available data show that production increases with the intensity of solar energy. The straight line of best fit for the experimental data on distillate (in pounds per square foot per day) plotted against the total solar energy received (in 1,000 Btu/sq ft/day) was found to be:

$$q_f = 0.1 + 0.333H .$$

The coefficient of correlation was found to be 0.54.

This straight line is in contrast with the predicted ceiling for production, regardless of how much solar energy is available. The solar energy available during the 4 months of experimentation, however, never exceeded 2,500 Btu/sq ft/day. Results of experiments in California reported by Howe [2] indicate that the most solar energy available was 2,500–3,000 Btu/sq ft/day.

Figure 6 again shows that production is very slow early in the day because of the time required for the cold body of water to heat up. Production at a higher rate starts approximately at noon and continues until 7 PM. Afterwards, production again slows down until the next morning and, for all practical purposes, actually ceases for a brief period. During the experiment, the highest water temperature reached was approximately 135°F.

Shallow Basin (Forced Convection)

Still 2 incorporates into its design the separation of the collector-evaporator unit from the condenser. Forced con-

vection is substituted for the natural convection present in the conventional design. The use of the plastic film provides a simple, lightweight collector-evaporator unit. A complete lack of collecting troughs further simplifies the design, construction, operation, and maintenance of this still.

In contrast with the deep basin, Still 2 produces almost continuously during the daylight hours (Fig. 6). The distillate production is small until 9 AM—that is, during the warm-up period. After 9 AM, production starts at a high

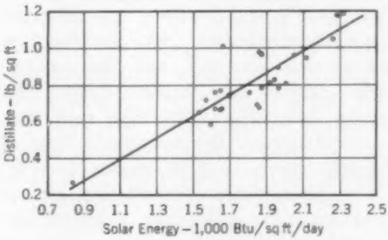

Fig. 7. Daytime Production From Still 2

The data are from the test period Jul. 24–Sep. 1, 1959. The improved efficiency in the distillate production was expected because the collector was mechanically separated from the condenser. The fitted equation of the straight line is $q_f = -0.266 + 0.597\ H$.

rate that virtually remains constant until 5 PM and then gradually decreases. The daytime production is almost fifteen times greater than the nighttime production. Some of the night distillate may be part of the distillate that remained in the condenser during the daytime In addition, the difference in temperatures constitutes a driving force for mass transfer, and some production will continue.

Data obtained during the experimental period showed the relationship between distillate and the amount of energy that reached the still (Fig. 7). The slope of the line of best fit is equal to 0.597, or more than 45 deg. The equation of the line was found to be:

$$q_f = -0.266 + 0.597H$$

with a coefficient of linear correlation of 0.88. The improved efficiency in the collection of solar energy was expected, because the collector was mechanically separated from the condenser. This permitted the continuous and proper functioning of the collector under any type of atmospheric condition. Figure 7 shows the increase of daytime production as solar energy increases.

The amount of distillate from Still 2 is the difference between the water content of the saturated air at collector-evaporator temperature and the water content of saturated, cooled air leaving the condenser. It was expected that both the amount of air passing through the system and the cooling effect of the condenser would be the most important considerations in still operation. Obviously, if the cooling capacity of the condenser is increased, the temperature of the air leaving the condenser will be lowered, and increased production can be expected. In this design, air functions primarily as the vapor carrier. Its capacity for carrying water is a function of temperature. The air that enters the system must first be heated up to the still temperature. Therefore, if the air is already at a high temperature before it enters the collector-evaporator unit, it requires less energy for heating up. Furthermore, for efficient operation, the air should become saturated at as high a temperature as possible with available solar energy. The relative humidity of the air as it enters the still is another important variable in the operation of this type of still.

The amount of air must be controlled to bring about its most efficient performance as a carrier. Experimentally, this was accomplished by passing air through the still until only a small strip of condensate remained close to the effluent end of the collector, indicating that the air leaving was saturated.

Shallow Basin (Natural Convection)

The only difference between Still 3 and the conventional design (Still 5) is the transparent roof material. The plastic film was used in the construction of the roof for this still. The behavior of Still 3 closely follows that of Still 5. The equation for the line of best fit relating production to solar energy is:

$$q_f = -0.064 + 0.239H.$$

Typical hourly production is shown in Fig. 5. The production follows closely, but is lower than, the production of Still 5. The difference is the result of the transmissivity of the plastic film and the type of condensation. It was found that the efficiency increases very slightly as the total solar energy increases.

Deep Basin (Forced Convection)

Still 4 was started on Jun. 11, 1959, and operated under four different programs. During the first two programs, it was operated without any sprays, in the same manner as Stills 1, 3, and 5. During the last two programs, a black perforated tray was mounted just inside the plastic canopy.

The characteristics of the four different operating programs were:

1. Prior to insulating the basin and forcing the air through it, the still was operated on the principle of the deep-basin design. This provided excellent control for the evaluation of the effect of insulation in deep-basin stills.

2. The basin was insulated and air was forced through the system. During this phase, the operation was identical to that of Still 2 (shallow basin, forced convection). The heat exchanger worked merely as a condenser; its effluent was drained to waste. The condenser was cooled by excess water with a temperature of approximately 73°F.

During daylight hours, air was blown through the still at the rate of 7 cfm (at this rate the plastic cover was clear), and distillate was collected from the condenser. At 7 PM the flow of air was shut off, and the condensate, which was formed during the night under the plastic film roof, was collected from the troughs. Typical hourly production is shown in Fig. 5. The nighttime production almost equaled the daytime production. Nighttime production was considered to take place from 9 PM to 9 AM, when the film was free of condensate. The blower was started at 7 AM.

3. Shortly after the second program began, a wall effect in the deep basin was observed. This effect allowed only a small portion of the sun's energy to be utilized. During much of the day, the angle of the sun's rays was too small to reach the black bottom of the deep basin. To overcome this problem, the perforated black tray was installed. This change not only provided for increased absorption of solar energy, but also permitted dispersion of water in the form of a droplet shower. For the third program, a small water pump was installed to recirculate the water between the basin and the perforated tray.

The effect from the intermediate tray was quite noticeable and the im-

provement sizable. Before installation of the tray, the production of Still 4 was 72 per cent of the production of the conventional Still 5, but it increased to 117 per cent after the improvement was completed.

4. A fourth program was studied to evaluate the combined effect of all variations previously discussed. The basin was drained every morning at 7 AM. The effluent from the heat exchanger was brought to the top of the perforated tray to provide preheated sea water. Although additional improvements in production had been expected as a result of the reuse of heat, this mode of operation was severely limited by the capacity of the heat exchanger. The maximum quantity of water that could be used with the 9-sq ft models could produce a tube velocity of only 0.15 fps, resulting in low heat transfer coefficients. This problem will be overcome by a redesign of the heat exchanger and an increase in the size of the still. With these modifications, results from the operation planned for the summer of 1960 should prove very interesting.

Results and Conclusions

On the basis of the observations made and the data collected during the summer of 1959, these conclusions were reached:

1. In comparison with the conventional Still 5, mechanical separation of the collector-evaporator unit from the condenser, plus forced convection with air as an intermediate substance, increased the amount of average distillate from 79 per cent in Still 3 to 170 per cent in Still 2. The maximum production for Still 2 was 1.224 lb/sq ft/day and is expected to increase further when all the improvements are completed.

2. Forced convection effectively removed the condensate from beneath the canopy. Therefore, there were no losses due to absorption and reflection by the condensate.

3. The operation of Stills 2 and 4, with forced convection, was found to depend on the amount of air used to carry the vapor through the stills.

4. Dropwise condensation, an inherent property of the plastic film, although more effective as a condensation process, reduced the overall still efficiency to 79 per cent, as compared to sheet condensation, a property of clean glass. This reduction may be the result of the increase of the index of reflection for solar radiation of the condensate in droplet form as compared to condensate in sheet form.

5. Droplet evaporation, although imperfectly achieved with an intermediate black tray in Still 4, increased the production on a typical day from 72 per cent of the production of the conventional still for flat-sheet evaporation to 117 per cent.

6. The nighttime production of Still 1 was, on the average, 160 per cent of the daytime production.

7. Production seems to be a function of solar energy. From the data collected, a linear relationship was found which is directly proportional to the solar energy. The experiment, however, was performed with an insolation of less than 2,500 Btu/sq ft/day. Other investigators reported that for greater insolations the production from the conventional still will decrease.

8. The straight line of best fit for a plot of 24-hr distillate production against solar energy shows a greater slope for the improved solar process of Still 2 than for any of the other processes used in experimental stills. The slope indicates that the relative

production from Still 2 will be even better with higher intensities of solar energy.

9. The average and maximum production values for different stills during the stated periods of operation are shown in Table 2.

10. Cost estimates, according to the standardized procedure set forth by the Office of Saline Water in March 1956, are shown in Table 3. To date, costs of operating solar stills are too expensive when compared to costs of alternative sources of supply or to costs of other desalting methods. Present distillation methods cost approximately $1.75 per 1,000 gal, and predicted cost, in the near future, is approximately $1.00 per 1,000 gal.

11. With the use of the principle of heat balance, an expression was developed which enables an intelligent estimation of water production from a deep-basin (forced-convection) still. For the derivation of an expression describing the operation of Stills 2 and 4, several simplifying assumptions were necessary: (1) the temperature of the incoming sea water, of the fresh water produced during the day, and of the air leaving the condenser were equal; (2) the temperature of the brine leaving the condenser, of the interior of the still, and of the brine in the collector were equal; (3) the temperature of the air entering the system, of the ambient air, and of the water produced during the night were equal; and (4) the temperature of the plastic cover is equal to the arithmetic average of the temperatures of air in the still and the ambient air. A few relatively simple calculations led to the equation:

$$q = \frac{eH}{\lambda(1-\alpha)\left(\dfrac{w_3 - w_1}{w_2 - w_3} + \dfrac{t_a - t_s}{t_i - t_s}\right) - \alpha(t_a - t_s)}$$

in which q is the production in pounds per square foot; e, the efficiency in per cent; H, the solar energy in British thermal units per square foot; λ, the latent heat of vaporization in British thermal units per pound; α, the ratio of night production to day production; w_3 is the moisture content of the air leaving the system; w_1, of the atmosphere; and w_2, of the air in the collector. The symbol t_a is the ambient temperature; t_s, the temperature of the incoming sea water; and t_i, the temperature of the interior of the still (temperature is in degrees Fahrenheit). In this expression w_1, H, t_a, and t_s are known, fixed quantities. The value of α varies from 0.1 to 0.2. The w terms are functions of tem-

TABLE 2

Production of Stills

Still	Production—*lb/sq ft/day*	
	Average	Maximum
1	0.312	0.526
2	0.848	1.224
3	0.349	0.592
5	0.499	0.698

TABLE 3

*Cost Estimates for Still Operation**

Still	Capital Cost† *$/gpd*	Operating Cost‡ *$/1,000 gal*
2	4.83	2.55
3	11.14	5.26
4	20.37	7.28

* Stills 1 and 4 were omitted from this study because they were not up to full efficiency for a protracted period of time.

† These estimates are based on actual costs incurred in building the small stills. The costs were then scaled up to a 100,000-gpd plant size. This procedure for estimating costs is not entirely accurate. In order to make more accurate estimates, an intermediate-size pilot plant would have to be operated.

‡ Total costs per 1,000 gal of product, including essential operating costs and such operating costs as amortization and overhead.

perature and relative humidity; λ varies with temperature, and its value may be obtained from numerous sources. The expression was utilized primarily for the determination of the efficiency, e.*

* For conventional stills, $e = \frac{q\lambda}{H}$.

Acknowledgments

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Main Extension Policies at Dallas

Henry J. Graeser

A paper presented on May 17, 1960, at the Annual Conference, Bal Harbour, Fla., by Henry J. Graeser, Supt., Water Works, Dallas, Tex.

THE 1949 and 1953 reports[1,2] of AWWA Committee A3.D—Water Main Extension Policy, showed that solutions to the problem of extension financing vary widely throughout the United States. Subsequent surveys reported in the JOURNAL by various authors since that time have shown that the variation in approach continues, but that many policies are the result of rapid growth and the necessity for emergency financing.

Committee Recommendation

The committee very wisely recommended a procedure for water main extensions based on calculation of the justified investment—that is, determination of the net operating revenue available for capital. The committee recommended a computation of the total annual operating revenues from all sources and a deduction of operating expenses from this to determine the net operating revenue. By dividing the net operating revenue by the total operating income, and by applying this percentage to the total estimated income for a new customer, that amount of a new customer's annual bill which would be available for capital charges can be determined. This amount is then divided proportionately to the plant investment in the smaller area mains directly serving such a new customer, and the balance of the income available for capital is to be reserved for plant and transmission capital charges.

In the example given by the committee, a fixed charge ratio of gross income to net operating income was assumed to be 30 per cent, and the annual revenue from a new customer to be $40. Thus, $12 per customer would be available to meet fixed charges on capital. At a 6 per cent capitalization cost, the $40 would support a $200 capital investment. Of the $200 available for capital, however, the maximum that could be allocated to the cost of local main extensions and fire hydrant branches was assumed to be 50 per cent. Thus it was estimated that $100 could be invested to serve a new customer. This was then reduced to a multiple of the gross annual income from the customer, or $40 per year in the hypothetical case. The $100 investment divided by 40 gives a factor of $2\frac{1}{2}$—that is $2\frac{1}{2}$ times the gross annual income from a customer is available for investment in extension facilities.

Limitation of Method

The committee stated, quite aptly, that this method probably would not yield enough money to warrant an extension of any great length. In fact, with a 100-ft lot and a cost of $5 per foot for minimum standard-size mains,

it can be easily seen that the extension could not be justified if the gross annual revenue were only $40 a year, as estimated.

It can be seen that any water main extension problem both for new development and for individual customers is a balance between equity to old customers in the city and the water rates charged. It is fairly obvious that in a fast-growing community the income from a new customer seldom supports the investment required to build the facilities to serve him. Almost invariably a considerable part of extension cost must be supported by water rates to the community as a whole, and part of the rate the old customer is called upon to pay goes to make up the difference between the justified investment and the actual cost of the extension.

Necessity for Expansion

As a matter of practical necessity, a city that annexes sparsely settled areas must face the problem of extending utility service to the existing developed properties and find means of financing the extension of facilities across vacant property. Inability to meet this problem has resulted in the surrounding of many central cities by a multiplicity of small municipalities, sanitary districts, and other governmental agencies which could, and did, develop their own water supply on a tax or other revenue-producing method. It may be that the inability of central-city water utilities to meet the requirements of expansion to undeveloped or sparsely developed areas has been responsible for the stifled economic situation many of these cities now find themselves in, with the expanding boom in suburban areas and declining values of downtown areas. Thus, from a practical standpoint, the committee's recommendation of a prudent investment rule is good only as a point of departure and by no means offers a solution. No general formula is applicable to all cities as an extension rule. Water rates, cost of service, the necessary investment in plants, reservoirs, and transmission mains are peculiar to each locale.

Refunds to Developers

It is well to recognize an apparent division in attitudes toward refunds to developers. The privately owned or state-regulated municipal utility may prefer to base its rates on the rate of return on invested capital. In choosing a policy of total refund to a developer or customer, the privately owned utility has a profit motive; it wants advantageous financing in the form of advance cash, but it ultimately wishes to return the money so that it can put the capital investment into the rate base. The state-controlled municipally owned utility, in turn, reaps the benefit of the state's "policy engineering" of rates, which is based on experience with privately owned gas, electric, and water utilities.

The uncontrolled municipally owned utility, on the other hand, can forget such matters. It does not seek a profit or is not required to establish its rates on a basis of rate of return on invested capital. It seeks only to serve equitably and efficiently at the lowest possible cost.

Dallas System

Dallas is probably as typical of the fast-growing, rapidly-expanding metropolitan area as any community.

Its extension problems are probably equal to those of any city, with its growth from about 45 sq mi at the end of World War II to its present area of 277 sq mi. Ultimate sewerage service has made annexation essential, and the city limits generally follow the drainage area boundary. At least 40 per cent of the land annexed to the city is still in farms or was sparsely developed by sporadic subdivision when annexed. It has been necessary to establish an extension policy which is not open to public attack and yet will assure the city's ability to finance extensions. Since World War II the water department has added an average of 100 mi of new water mains to the system each year to serve 6,000–9,000 new customers annually. This rate of growth has quickly brought to light the tremendous off-site investment necessary to support each new customer.

Water is dear in the Southwest, and the available supply close by is inadequate to meet the area's ultimate potential growth. For this reason Dallas has acted very swiftly to develop and obtain water rights for the future growth of the city in advance. It has been necessary to place an additional financial burden on the present population in order to secure the future of the whole community, and only limited funds are available to finance local extensions.

Connection Charges

In the face of this kind of growth, many Texas cities, like Dallas, have adopted a policy of charging a connection charge prorated according to street address front footage. This charge, generally, is aimed at the actual cost of one-half of a standard 6- or 8-in. water main. Under this system, the new customer pays for one-half of the cost of the minimum standard main for the distance across his street address frontage. Extension across vacant property is a risk taken by the utility pending development. Dallas and most area cities will install and bear the cost of a 100-ft maximum extension to reach a new customer's property line. This distance, plus street intersections, plus one-half of the cost of the line across the street from the customer's property must be financed from present income. Any extension longer than 100 ft requires a deposit of the total cost of the excess until others connect. In a typical subdivision, even when all available frontage is connected, only 70 per cent of the line length is assessable street address frontage; thus 100 ft of line has a front footage of 200 ft, but only 140 ft of prorated charge can be collected. This almost invariably means an initial loss of funds. The difference is financed through the rates of all customers. Collection of prorated charges from vacant property is kept in a revolving capital account to reduce the borrowed capital for area extensions.

A typical lot in Dallas has 75 ft of frontage. If there is a 60-ft street and one vacant 75-ft lot between the applicant and the existing water system, the total linear footage of the extension is 210 ft. Only 150 ft of the line lies along property frontage, however. At \$5 per foot, the line cost is \$1,050. A prorated charge of \$1.70 per front foot is collected from the single applicant for his 75 ft, or \$127.50. This leaves \$922.50 to be financed. Ultimately three vacant lots along the line will connect (there are two across the street), adding three more charges of \$127.50, or \$382.50. This leaves a

net cost of $540.50 to be financed. A typical residential customer's annual water bill finances $87.50 of local extension. Four such bills would finance $350. Subtracting $350 from $540.50 leaves $190.50 to be financed from other sources.

As can be seen, either the new customer must finance the total cost of each extension and have it refunded to him as others connect, or everyone must share the load. By raising prorated charge to about 1.4 times the average actual cost of 6- and 8-in. mains and appurtenances in place, the total cost of the extension could be recovered. The only other alternative is a discriminatory rate that would charge off the total cost of the extension to new customers. This is unfair, unpopular, and unworkable. Almost nowhere in the United States will state courts or utility commissions allow any utility to charge a discriminatory rate to new customers other than a connection charge. Some do allow long-term payment of such charges on the monthly water bill with refunds as other customers connect. The bookkeeping for such a scheme on a large system is a formidable task. On the other hand, if a compromise is made on the connection charge so that it does not cover the financing of the whole extension distance, the balance must be paid for by the rates charged to all customers.

Subdivisions

More debated than individual extensions are extensions to entire subdivisions. There has been a growing policy in the Southwest to require land developers to install minimum standard water systems in new subdivisions at their own expense. As stated previously, cash financing of the total cost is the only method that does not result in forcing other customers to share in the financing of extensions. In new developments, long-term financing in the home mortgage makes it practical. The costs of oversize and off-site mains are refunded upon completion and paid for out of the general water rate. The cost of the basic system is passed on to the new homeowner who pays this cost over the life of his home mortgage. Such a new customer, along with the old, pays in his rate his share of the debt service charges on off-site facilities, plants, reservoirs, and water supply development plus the cost of engineering, inspection, and refundable amounts paid to developers. Many cities are arriving at the conclusion that there is no actual refund due a developer for his investment in a water system, except for the costs of facilities not directly used by his development. The developer is in a business in which the growing community offers him an opportunity to make a profit. The utility is as essential to his development as the development is to the utility. In most instances, unless a refund is made to the developer immediately upon completion of the development, the price of the system must be made part of the lot cost, as most development financing is very short term and most developers are not willing to wait for refunds.

Evolution of Dallas Policy

Dallas' financial plan demonstrates how one rapidly growing city has met the problem of subdivision extensions. The present policy is a result of evolution rather than a one-time revision. No city should make a sudden adjustment resulting in a significant cost increase to developers. Dallas initiated a prorated charge in 1936. At that

time, too, the land developer was charged only the prorated amount, and the balance of the subdivision system was financed by bond funds. This resulted in approximately 50 per cent developer participation in cost. Individual extensions were made upon payment of a prorated charge if the applicant's property was not more than 150 ft from the nearest water main. The water department operates and maintains the sewer system also, and the extension policy for sewerage was identical. In 1951 the housing boom made necessary swift action. The land developers requested permission to let their own private contracts under city inspection and specifications. This gave rise to a system of evaluated costs as a basis for off-site refunds. The land developers agreed to figures generally 10 per cent less than the average cost of such facilities. Engineering was done at the developer's expense subject to water department approval. Refunds were made of the difference between the prorated cost and the evaluated cost of the system as installed. In 1954, owing to a lack of funds, the city could no longer continue this pol-

TABLE 1

Apportionment of Total Cash Requirements Projected for an 11-Year Period, 1959–70

Apportionment Item	Percentage of Water or Sewer Plant	Percentage of Total Plant	Cash Requirement $	Collections Other Than Revenues $	Net Cash Requirement From Rates $
Water					
Operation	41.19	29.23	77,092,671	1,699,259*	75,393,412
Capital	0.09	0.06	9,420,861	3,635,779† 5,624,784‡	160,298
Debt Service	55.05	39.06	101,570,475	804,122	100,766,353
Other	3.67	2.60	6,762,176	53,535	6,708,641
Total	100.00	70.95	194,846,183	11,817,479	183,028,704
Sewer					
Operation	44.92	13.05	36,090,692	1,973,682§ 447,886*	33,669,124
Capital	0.00	0.00	2,669,566	374,350‖ 2,295,216‡	0
Debt Service	51.43	14.94	38,846,335	307,542	38,538,793
Other	3.65	1.06	2,759,334	21,845	2,737,489
Total	100.00	29.05	80,365,927	5,420,521	74,945,406
Water and Sewer					
Total	—	100.00	275,212,110	17,238,000	257,974,110

* Miscellaneous operating income.
† Water taps charges.
‡ Frontage connection charge and value of developer systems contributed.
§ Industrial sewer surcharge.
‖ Sewer lateral charges.

icy. Subdividers were notified that no further extensions could be made unless they bore the whole cost, including off-site mains. The city was able to finance refunds from cash reserves and whatever was collected from individual applicants on such mains to pay the increment on oversize transmission mains. After a year of this, a new bond program was passed, but water rates allowed only limited participation with land developers. During all this time, of course, individual extensions were made, and the maximum connection distance was reduced to 100 ft. In 1956 the program now in effect was introduced.

Since 1956, the land developer pays the total cost for that part of the system directly serving his land development. The cost of off-site lines or side lines serving other properties is refunded on evaluated-cost scale. Costs of oversize lines in excess of 8-in. water or sewer mains are refunded. Inspection, engineering, and refunds amount to an immediate cash outlay under this policy of about 20 per cent.

Calculation of Available Income

To give an idea of the income available from new customers, a typical residential billing district has been selected for examination. The average revenue for water and sewerage service from this district was $85.12 per customer year. Table 1 shows an 11-year forecast of costs. This includes a major capital program for a water reservoir and transmission system of $109,410,000 over the next 11 years and $39,470,000 for sanitary sewers and treatment plant expansion. This is estimated to involve a cumulative cash requirement of $275,212,110 for all expenses over that period. All contributions in aid of construction are then deducted from these costs. Contributions include prorated charges, the total cost of developer systems, sewer tap charges, and water service charges. A net cash requirement of $257,974,110 remains to be supported by water and sewerage rates. The relationship of operating expenses to capital is shown in Table 1. Of total costs, the water system will require 70.95 per cent of the income and sewerage 29.05 per cent. Operating expenses are 41.19 per cent of the water budget and 44.92 per cent of the sewerage budget.

Table 2 shows the projected book value of the water and sewerage system in 1970. The net area system consisting of mains of less than 12-in. size, after deducting contributions, will represent only 18.58 per cent of the water system capital value and 42.2 per cent of the sewer system capital value (Table 2). Contributions in aid of construction accumulated since 1945 will, by 1970, account for 50 per cent of the value of the system area served by mains under 12 in. in size. In Table 3 the allocation of cost is applied to a typical average water and sewerage bill of $85.12 per year.

Table 1 shows that 70.95 per cent of the combined water and sewer income is for water service and 29.05 per cent for sewerage service, or $60.39 for water and $24.73 for sewerage. Of these amounts, total debt service requirements are 55.05 per cent of the water cost and 51.43 per cent of the sewerage cost. Thus the annual amount of the average customer's bill available for debt service is $33.24 for water and $12.72 for sewerage.

Table 2 sets forth the projected book value of the system. The capital value listed under customer costs represents the net value of the area water mains 12 in. and under, after deduction of

contributions in aid of construction, such as prorated charges and the value of developer's systems. This figure includes refunds on oversized and off-site mains built by developers. The net figure is further reduced by estimated future prorated collections on off-site mains presently listed as a capital expense. This leaves a net capital investment to be carried by rates of 18.58 per cent in the area water system. Thus, of the annual water income available for debt service ($33.24 per customer), 18.58 per cent is allocated to area system extension, or $6.17 per customer per year.

TABLE 2

*Allocation of Projected Book Values of Water and Sewer System by Class of Service, 1970**

Service Class	Value of Plant in Service Class $	Percentage of Water or Sewer Plant	Percentage of Total Water and Sewer Plant	Plant Provided by Others $	Plant to Which Debt Service Is Allocated†		
					$	Percentage of Total-Plant Allocation	Percentage of Total Water or Sewer Allocation
Water							
Area distribution, meters, fire hydrants, and services	65,356,831	31.91	21.95	33,481,464	31,775,367	13.30	18.58
Transmission and treatment facilities	87,660,909	42.86	29.49		87,660,909	36.68	51.25
Impounding reservoir	51,614,729	25.23	17.36		51,614,729	21.59	30.17
Total	204,532,469	100.00	68.80	33,481,464	171,051,005	71.57	100.00
Sewer							
6–12-in. Mains	53,478,275	57.66	17.99	24,820,286	28,657,989	11.99	42.19
Mains larger than 12 in. plus treatment facilities	39,274,428	42.34	13.21		39,274,428	16.44	57.81
Total	92,752,703	100.00	31.20	24,820,286	67,932,417	28.43	100.00
Water and Sewer							
Total (all classes)	297,285,172	—	100.00	58,301,750	238,983,422	100.00	—

* Present water and sewer rates based on an 11-year program of construction.
† Value of plant in service class minus plant provided by others.

Of the annual sewerage income available for debt service ($12.72 per customer), 42.19 per cent is allocated to extensions, or $12.72 per customer per year.

Dallas finances its program on 20-year revenue bonds. Assuming a 4 per cent interest rate or bond sales over the next 20 years, $1 per year will finance $14.18. Thus, from the income of an average residential customer, the following amounts can be financed for water and sewer area extensions (Table 3): for water, 14.18 ×$6.17, or $87.49; for sewerage, 14.18×$5.37, or $76.15. The total for water and sewerage is $163.64 per customer per year. This gives a justified investment ratio of 163.64/85.15, or 1.92.

The example given above represents new subdivisions, where water usage is higher than the average. To base available capital on the guaranteed income, the average water and sewer bill for residential customers must be used. This amounts to $75 per year per customer. At a ratio of 1.92, this average income will support an investment of $144.15 per new customer.

The annual average program outlay for extension replacements and relocations in the forthcoming 11-year period is $956,363 for water and $1,272,727 for sewerage, or a total of $2,229,090 per year.

In a typical year, water and sewerage refunds and inspection expense on new developments amount to $182,000 and homeowner extensions amount to $833,000, or a total outlay of $1,015,000. The income from an average 6,500 new customers per year will finance $936,000.

Actually, with a typical revenue from a new subdivision of $163.34 per customer per year, a capital outlay of $1,061,710 would be justified. The new customer would be supporting the annual extension cost. Because only 70,000 customers were connected to the Dallas system in 1940, as compared to the present rate of 187,000 per year, it appears that the majority of customers are served by facilities on which debt payments are still being made. If the 70,000 customers connected in 1940 are assumed to be using debt-free facilities, it can also be reasoned that their contribution is offset by the annual cost of replacement and betterment, which just about equals programed expenditures for extensions. This is, in effect, the reserve for depreciation for a system operating on a cash basis. No actual reserve is budgeted other than the replacement program.

TABLE 3

Revenue Available From Debt Service Allocation for Main Extensions

Item	Amount per Account—$	
	Water	Sewer
Avg annual income	60.39	24.73
Portion of income available for debt service*	33.24	12.72
Portion of debt service funds available for extensions†	6.17	5.37
Extensions that can be financed with available debt service funds‡	87.49	76.15

* 55.05 per cent for water; 41.43 per cent for sewers.
† 18.58 per cent for water; 42.19 per cent for sewers.
‡ 20-year bonds at an interest rate of 4 per cent (financing $14.18 with $1 per year).

Although some might debate the equity of the program, it is certainly more equitable than ad valorem taxes or a water rate which would support the total cost of area extensions without contributions in aid of construction.

Perfect equity is a desirable objective, but it is not always attainable.

Summary

An extension-financing policy must first meet the practical problems of answering reasonable demands for new service and providing future capacity. A way must be found to finance these which is within the means of the new customer as to cash outlay—and within the means of all customers as to their general water rate.

The rate at which new customers are being added is a key consideration. A city with a debt-free system and a surplus can carry out a more liberal extension policy than that city which triples its customers in 15 years. Many of the larger, older cities had a practically debt-free system when the boom began, with nearby cheap sources of supply. This, no doubt, eased the shock of sudden expansion, if they were able to get even modest rate increases before depleting reserve funds.

Availability of primary raw water and the type of service area are important factors. The semiarid Southwest and West face a much more expensive expansion problem than areas of abundant rainfall or prolific ground water reserves. A sprawled city averaging three houses per acre, each with a green lawn, offers a far more expensive extension problem than row houses. But, in any city which is growing rapidly and requiring extensions, all customers must share partly in the cost of extensions or the cost to individual new customers will be exorbitant. After all, no one ever buys a share or equity in the water system; it is a going business. One does not get an automobile cheaper because he has bought the same brand for 20 years. One gets service at the going cost of providing that service.

When the extension boom passes, all customers will share in refunds in the form of reasonable water rates. Cash refunds to a developer for creating new customers are not justified, particularly when the developer could not get customers for his property if water service were not available.

References

1. COMMITTEE REPORT. Main Extension Policy. *Jour. AWWA*, 41:729 (Aug. 1949).
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Winning Public Support for Bond Issues

Joint Discussion

A joint discussion presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla.

Fergus Falls—*Howard J. Sowden*

A paper presented by Howard J. Sowden, Supt., Public Utilities Dept., Fergus Falls, Minn.

ON Sep. 15, 1959, the citizens of Fergus Falls, Minn., approved a \$1,500,000 water improvement referendum with 90 per cent of the votes cast, the largest majority ever recorded in the city of 13,000. The 20-year expansion program was given an outstanding vote of confidence. The success of the referendum was largely due to proper public relations as practiced in years past.

Public Relations

There are two basic principles of good public relations: (1) to do a good job, and (2) to let the people know about it. An informed public is more likely to have confidence in its administration and more interest in the progress of the community.

Water utilities serve a larger and more varied class of consumers than any other business, except perhaps for electric utilities. Providing consumer satisfaction is an important task for the water utility as it is for any public service organization. Most utilities as well as other businesses have long ago come to the conclusion that the "public be damned" attitude, which was so very prevalent in past years, is wrong and wasteful. There has been an obvious change in attitude by the utilities from a policy of little or no concern about the type of service rendered the consuming public to a policy where an earnest endeavor is made to secure better public relations. The effort is made generally through a thorough information program regarding the problems and expenses of operating a utility and by rendering the most prompt, efficient, and courteous service possible. In the larger utilities, the information program is generally handled by a public relations department.

In the smaller water utility, such as that in Fergus Falls, the expense of a public relations department would probably be considered unwarranted because of the relatively small size of the business; therefore, it is necessarily one of the duties of the manager to promote and carry out a satisfactory program of good public relations.

In its dealings with the public, the Fergus Falls utility assumes that most people are fair and are not only inter-

ested in receiving prompt, efficient, and courteous service, but also like to be informed of the problems and work necessary to provide that service. Advantage is taken of opportunities to explain to various public groups the many elements of cost incurred in obtaining, treating, and distributing water to their homes and business establishments.

A water utility manager can enhance his public relations program by joining one of the many local service clubs and by assisting in community projects, thus keeping his name and his utility's problems before the public.

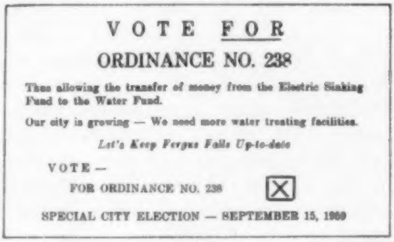
One of the greatest problems facing the manager of a publicly owned utility is that of conducting a referendum to obtain the necessary funds for a large-scale expansion of water treatment and distribution facilities. This problem is amplified when it is realized that it is faced by the average manager only once or twice in his lifetime, and that he therefore has little experience at it and must seek the advice of others. In Fergus Falls, a copy of a community relations portfolio issued by the Cast Iron Pipe Research Association was obtained [1] and proved to be of great assistance in guiding and conducting the bond issue campaign.

Analysis of Requirements

For a number of years it had been recognized that Fergus Falls was rapidly approaching a point where the capacity of its lime-softening plant would be exceeded. This was reported in the annual reports and on numerous occasions. The fact was given publicity through the various news media and was also mentioned during talks given before service clubs and other organizations.

In 1945 the average pumpage was 650,000 gpd; by 1958 it had jumped to 1,500,000 gpd. A firm of consulting engineers was engaged to study the water system facilities and to make recommendations for a 20-year program of improvements.

Engaging the services of a consulting firm for this type of study is a must for all except perhaps the largest water utilities. Consultants are able to approach the many problems encountered in an unbiased manner. Furthermore, the burden of proof of the needed im-


VOTE FOR

ORDINANCE NO. 238

Thus allowing the transfer of money from the Electric Sinking Fund to the Water Fund.

Our city is growing — We need more water treating facilities.

Let's Keep Fergus Falls Up-to-date

VOTE —

FOR ORDINANCE NO. 238 ☒

SPECIAL CITY ELECTION — SEPTEMBER 15, 1959

Fig. 1. Fliers Used in Bond Issue Campaign

Several thousand of these fliers were sent out by Fergus Falls merchants with their September 1 statements. The expense was borne by members of the local citizens committee.

provements is lifted from the shoulders of the manager.

In February 1959, the engineering firm submitted its formal report recommending total improvements over the next 20 years of $1,500,000 with an immediate outlay of $950,000. It was decided that the best means of financing the program would be to raise the water rates approximately 50 per cent and to ask the voters to approve the transfer of $570,000 from the electric-power sinking funds, the balance, or

$380,000, to be financed by a future bond issue which is to be supported by the increased water rates.

Information Campaign

An information campaign was then launched by preparing a fifteen-page mimeographed summary of the situation. This related the history of the water system since it was founded in 1883, traced the growth of the city's water use, summarized the engineering report, which predicted a growth from 13,000 to 21,000 by 1980, and finally pointed out that it was up to the people of Fergus Falls whether there would be enough water for the future.

The engineering report, along with the mimeographed summary, was distributed to the library, the newspaper, the radio station, and influential people in the city. In publicity releases all interested persons were invited to review the above reports with utility personnel.

Assistance From Women

Very fortunately, the League of Women Voters of Minnesota and North Dakota had a program of studying the water resources and needs of the Red River Basin. The local chapter of the league was part of this study group. They were presented with several copies of the water utility's reports for study and comment. The reports were reviewed with them and the group was given a tour of the water facilities. The same was done for other women's groups. Convincing these groups of the utility's needs was a large factor in the ultimate success of the referendum.

The importance of the housewives was deliberately accentuated, as, after all, they are the users who most appreciate having a safe, soft, and palatable water. Furthermore, it would be a grave mistake indeed to overlook the power of the woman's vote.

Citizens Committee

Several months before the date of the referendum a group of twenty businessmen, the newspaper editor, and the radio station management were invited to a meeting to discuss water needs. This group was then invited to form a progressive citizens organization to study further the city's needs and to assist in the presentation of the facts to the public. The response of this group was most gratifying and the campaign was taken over by them. During the weeks prior to the election small groups of no more than five met with the manager for discussion and clarification of questions. This made for easier contact and short, to-the-point meetings. The manager was complimented many times for the success of this effort and type of presentation.

During the discussions and the campaign, the newspaper and radio managements were kept fully informed of developments. From July 1, when the picture of the League of Women Voters appeared, until election day on September 15, fifteen stories of various types appeared in the Fergus Falls *Daily Journal*. These included lead stories about the information of the citizens water committee, a question-and-answer interview with the utility manager, two editorials urging passage of the referendum, and endorsements by various groups. The radio station also cooperated fully.

Talks were given before all service clubs and parent-teacher groups. The manager requested that a member of

the utilities commission give most of the talks, while he stayed in the background in order to answer any questions.

The laws of Minnesota do not allow the expenditure of public funds for advertising any controversial subject. When this was explained to the citizens committee, the members offered their own funds. The optimism of this group was so great, however, that they felt the purchase of advertising space was not needed. There was no development of opposition at any time. The only expense incurred was for the printing of several thousand fliers (Fig. 1) which the merchants mailed out with their September 1 statements. The expense was paid by several businessmen.

Conclusion

A 50 per cent water rate increase was put into effect on Jul. 1, 1959, with some misgivings, for it was felt that it would have an adverse effect on the coming election. Because of the full publicity about the increase and the needs, however, there were virtually no complaints about the increase. Furthermore, the action apparently had no adverse effect upon the success of the referendum, which was passed by an overwhelming majority on Sep. 15, 1959.

Reference

1. *Water Utility Executive's Community Relations Portfolio.* Cast Iron Pipe Research Association, Chicago, Ill. (1959).

Denver—*Robert S. Millar*

A paper presented by Robert S. Millar, Mgr., Board of Water Comrs., Denver, Colo.

It should be obvious that a sympathetic electorate is the one most important requisite to a successful bond issue for water utility improvements. A sympathetic electorate cannot be created overnight, however. Public goodwill must be carefully developed. The responsibility of water utility management in developing public goodwill is twofold: first, it must see that the utility deserves it, by providing, with the aid of capable, conscientious, and properly paid supervisors and personnel, the best and most efficient service possible at the lowest possible cost; and second, it must make sure that the public is aware of the utility's problems and needs, as well as of the value of the service it provides. Only an informed public can be a sympathetic public, and when the need for a bond issue arises it may be too late to begin to educate the voter.

Public Information

The tools of public information are many and varied. The cooperation of the press, radio, and television should be enlisted at every opportunity. When necessary, special surveys and reports by experts should be made and used to reinforce the recommendations of local utility officials. Such reports should be made available not only to city officials but should be taken to and explained to such representative groups as the local chamber of commerce, League of Women Voters, junior chamber of commerce, church groups, labor unions, and the public

expenditure council. These groups should be encouraged to inform the utility of their reactions. If at all possible, their findings should be made public so that the community may know the results of their studies. Public appearances by utility personnel at service clubs, women's organizations, and special meetings are effective. Booklets and brochures setting forth the history, operation, and plans of the utility and motion pictures for showing in local theaters, at public meetings, and in schools are extremely valuable tools.

Denver Program

In 1955, Denver's water board found it necessary to request that a $75,000,000 bond issue be approved for water supply improvements. A citizen's committee was formed and volunteers from that committee carried the message to various groups in the city. A speaker's kit containing booklets, brochures, and financial statements was prepared for their use. It is felt that the talks before public meetings and small groups of citizens did much to promote the eventual passage of the bond issue.

The Denver Water Board has been very fortunate in its relationships with the press, radio, and television. When it became known that a bond issue was to be voted on, both daily newspapers requested additional information and assigned special reporters and photographers to cover the story and inform the public of the issues. In addition to regular new releases, special features appeared in the Sunday supplements, and special articles appeared during the week. For a week before the vote, the evening paper carried front-page reminders, in heavy type, to vote on the water bond issue. The reminders emphasized the importance of the issue and urged an affirmative vote.

A motion picture, 28 min in length, had been made to stimulate public awareness. The television stations used short sections cut from the film for 1–2-min spot announcements. Radio and television programs featured panel discussions on Denver's water needs. "Prestige spots," 1-min appeals by well known businessmen and civic leaders, were used by the radio stations. One minute film trailers were run at the movie houses.

Billboard space was donated and bus cards were prepared for showing in buses 10 days before the election. Truck signs were also prepared and many of the truck fleet owners placed them on their trucks for a week before the election. Several of the local merchants, bankers, and building and loan associations prepared displays calling attention to the need for water utility improvements.

Continuing Program

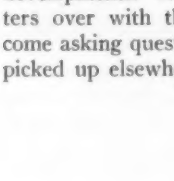
After the bond issue had been passed by more than a 14–1 vote in August 1955, the Denver Water Board continued to report regularly to the public through every possible medium of communication. The *Denver Water News*, a four-page publication, is sent to all customers with their water bills. The newspapers have continued to run frequent stories on the large construction projects. The board's members and staff continued to appear before civic groups, service clubs, and all who were interested in hearing about the progress being made, and how the $75,000,000 was being spent. Appearances by the staff and board members

on television and radio have helped to keep the public informed of progress. A new type of annual report, written so as to be interesting and informative to the average layman, is sent to all customers. A moving-picture record was kept of all major construction projects so that another motion picture could be made. The movie was completed in 1958 and was shown to many groups in preparation for *another* bond issue—this one for an additional $40,000,000. The new issue was put before the public for approval in October 1959, and it was passed by a 3–1 vote, even though a 35 per cent rate increase had gone into effect 7 months before.

Wherever possible, the Denver Water Board has tried to anticipate developments. It has tried to talk matters over with the press before they come asking questions about some lead picked up elsewhere. It is the exception, rather than the rule, that the newspapers have to ferret out information to get a story about the board's activities and plans. By knowing the background of incidents that could ordinarily lead to a bad news story, reporters are better able to cushion the blow when the story breaks.

Conclusion

Preparing and disseminating background information cannot be done all at once; it must be an everyday job. Public confidence inspired by years of an open-door open-books policy sets the stage for public acceptance of improvement programs. A well informed group of consumers that has received good service and has confidence in the water utility's policies and management will support any carefully thought out program of necessary improvements.



Selection of Equipment for Machine Billing Operations

Joint Discussion

A joint discussion presented on May 17, 1960, at the Annual Conference, Bal Harbour, Fla.

Richard D. Tompkins

Comptroller, American Water Works Service Co., Philadelphia, Pa.

IN recent years, great progress has been made in the development of both key-driven and electronic billing equipment. One of the principal problems facing most utilities today is the selection of the proper type of equipment to perform customer-billing and accounting functions in the most economical and efficient manner. Today, equipment available to even the small utilities materially reduces the problems incidental to the feasibility of using mechanical equipment for billing and accounting. The versatility of even the less costly key-driven machines justifies the required capital investment, even though the customer-billing load is not sufficient to require the full-time use of the equipment for this purpose. The point to be made is that, in most instances, through the simple expedient of changing control bars or panels, the machines can be adapted for uses other than customer billing, such as for preparation of payrolls, voucher checks, and accounts payable records. Billing machines, however, should be used for these additional jobs only after careful consideration has been given to work load factors and proper programing of the various machine functions.

Survey of Practices

The first and most important step in any plan for the purchase or rental of machine equipment for billing and accounting is to conduct a complete and thorough survey of present utility practices in order to determine the feasibility of machine application to various billing and accounting functions. Most water utilities probably will not have employees within their own organization who are qualified to conduct this type of survey. These utilities should employ an outside firm of public accountants or management consultants who are able to furnish the full range of management services. Although most of the larger manufacturers of machine accounting equipment offer the services of their staffs in making such a survey, it may not be wise to accept their recommendations alone, for, quite obviously, they are primarily interested in the sale of their equipment. After the survey of present procedures is completed, the utility should be in a position to know generally what basic type of equipment—key-driven or electronic—will be best suited for the job.

Types of Machine Billing

If the survey indicates that the work load is not sufficient to justify the cost of electronic or punch card equipment but does warrant the purchase of key-

driven machines, then, of course, a decision has to be made on the type of equipment most suitable for the job. This decision depends on several considerations.

Three basic plans for machine billing of customer accounts are available: stub plan, register sheet plan, and bill and ledger plan. For medium-sized and larger utilities, the stub plan has proved to be not only the most economical but also the most efficient plan; therefore it has been adopted by most utilities. Some small companies have adopted the register sheet plan, primarily because of the limitations of the machine equipment that they can afford to purchase. The bill and ledger plan has had very little acceptance by utilities, mainly because it is the least efficient of the three plans.

Equipment

The machines made by some manufacturers are more suitable for multiple-line bills; those of other manufacturers are more efficient in the preparation of single-line bills. Where machines are to be used for accounting functions in addition to customer billing and accounting, the ease of adapting the equipment to other jobs is of primary importance. Furthermore, the equipment maintenance services offered by various manufacturers should be carefully analyzed, both from the standpoint of cost and the promptness with which service calls can be answered.

The purchase or rental of electronic or punch card equipment should be considered only by large utilities with a sufficient potential work load to justify the cost of the equipment. Such companies have approximately 100,000 or more customer accounts. Companies with the minimum number of accounts within this range should use the equipment for customer billing and accounting and also for general accounting functions, otherwise the capital investment or the cost of renting the equipment may not be warranted.

It should be understood that a self-contained utility can use punch card equipment for all phases of customer billing and accounting operations, including preparation of customer bills, posting of cash and other entries to customer accounts, consumption and water sales summaries segregated by revenue classifications, and ledger controls. Therefore, if these self-contained utilities plan to purchase or rent equipment for customer billing, they should consider using the equipment for all phases of customer billing and accounting, from the standpoint of having an economical and efficient operation.

Central Billing Office

A large system of utilities, such as the American Water Works Co. group, can offer a choice of the type of billing equipment to be used by the various utilities in the system. Wherever possible, this company has established central billing offices to serve groups of utilities, with the billing office usually located in the office of the largest member of the group. Of course, this is done only when the utilities in the group are within a reasonable distance of the central billing office and the transportation facilities are such as to provide overnight delivery of meter books and bills between the billing office and the offices of the individual members of the group.

At the central offices where key-driven machines are being used, the billing and addressing equipment provided varies in number and type of units, depending on the number of customer accounts to be billed, the

number of single- and multiple-line bills, and various other load factors. In these offices, the machine equipment is used solely for the preparation of customer bills and for the byproduct operation of preparing sales register sheets or a carbon copy listing of the individual bills and totals of consumption and revenue segregated by revenue classification. The totals of consumption and revenue billed are provided by the billing machine registers that accumulate these totals during the course of the billing operation.

Stub Plan

With the exception of one small utility using the register sheet plan, all the other utilities that are part of the American Water Works Co. system use the stub plan of customer billing and accounting. With this system, a three-part card form is prepared on the billing equipment to provide: (1) a postcard bill to be sent to the customer; (2) a followup or delinquent notice section; and (3) an office ledger stub. Each of the first two parts has a subsection known as cashier's coupons, which are detached at the time of payment and used for recording and posting cash collections of customer accounts.

Proof of the accuracy of the consumption billed is mechanically established by a line proof of the subtraction of the previous meter reading from the present reading. Verification of the charges billed is accomplished through an independent adding machine listing of the amounts of the charges. This operation is done by a clerk using the meter books and billing charts.

At the present time, the company is using punch card equipment at only one of its central offices. This office is located in the same building as the office of the second largest utility in the system and is within a reasonable distance of approximately 40 utilities in the system. Although the customer billing load of these 40 utilities—100,000 customer bills per month—is sufficient to justify the use of punch card equipment, the equipment is being used for both general ledger accounting and customer billing and accounting. In addition to addressing and preparing the bills and sales register sheets for all the utilities in the group, the punch card equipment is also used for posting cash collections and all other phases of customer billing and accounting operations of the utility located in the same building as the central office. This utility alone is presently serving approximately 86,000 customers, who are billed principally on a quarterly rotary basis.

Further Considerations

Ordinarily, where a company does its own billing within a single rate structure, the purchase or rental of an electronic calculator for use in calculating the amounts of bills would prove to be more practicable than the type of equipment the American Water Works Service Co. is using for the same purpose. But because the central office does the billing for 40 different rate structures, the use of a system of interspersed gang punching of the amounts of charges from prepunched master rate cards into billing cards proved to be more practicable.

Inasmuch as this installation was the company's first venture into the field of electronic or punch card equipment, it was thought advisable to employ the services of outside consultants to assist the system and methods staff in the selection and installation of the proper equipment for the various functions to

be performed. The outside consultants were retained until all phases of the machine operation were well underway and the various problems incidental to an installation of this size completely resolved.

Summary

When considering the purchase or rental of mechanized billing or accounting equipment, a utility should:

1. Thoroughly survey its present procedures with a view not only to determining its billing and accounting functions that can be done more efficiently with a machine operation, but also with a view to improving and simplifying its present practices
2. Employ outside consultants for assistance in making the survey, for advice about the proper equipment to be purchased or rented, and for assistance with the installation and the actual operation of the machine system in its initial stages
3. Consult with other utilities using equipment similar to that which will be purchased and, where possible, carefully review their machine billing and accounting procedures.

John G. Copley

Gen. Mgr., Elmira Water Board, Elmira, N.Y.

The terms "large utility" or "small utility" are, of course, relative, dependent on the area in which the utility is located. Although the system at Elmira, N.Y., may be considered large by the many smaller utilities within a 50-mi radius of the city, the Elmira utility is definitely in the small-utility category. This discussion will, therefore, concern utilities that bill less than 20,000 meters. Many articles on machine billing have already been published. Most of them pertain to specific practices of a utility or a manufacturer. Thus, an opportunity exists to generalize on the procedures required to set up machine billing or to revise and modernize a machine billing operation that may be outmoded.

Small ultilities usually do not have available, and cannot afford to have as a member of the regular staff, an expert in office machinery and accounting practice. Therefore, an investigation of utility procedures and a decision on whether machine billing should be used are usually in the hands of the utility manager or superintendent, who may have an engineering background. Fortunately the techniques used in studying problems of machine billing are much the same as those required for almost any other engineering problem of water supply management. The methods and procedures normally used are applicable to the problem of increasing the efficiency of office operation through the establishment of machine bookkeeping operations.

Preliminary Procedures

The first step in setting up a machine billing operation should be the determination of the size of the job to be accomplished. Just as it would be inadvisable to buy a 10-mil gal pump for a 5-mil gal job, it would be wasteful of capital funds to purchase machine billing equipment that can turn out the entire billing of a utility in a few hours. When the size of the billing problem is being determined, consideration should, of course, be given to the rate of utility growth. The equipment that may finally be purchased should meet future requirements for a period of 5–10 years and meet the expected increase in the total number of customers.

The second phase of the investigation should concern existing conditions in the utility. Are present procedures

so established that the change to machine billing would be more efficient? Has the utility established a system of cycle reading of meters and billing, so that the machine to be used will not be overloaded with peak periods? Will the flow of work be steady to provide an even work load? If the proper conditions do not exist, an investigation should be made of the changes required to provide a proper basis and flow of information for a machine billing operation. Factors to be considered may include the dividing of the service area into sections for billing periods, geographic meter routes, and the renumbering of various accounts to fit in with machine billing procedures. The changes in existing office procedures and methods should match the planned billing method.

In this period of investigation of existing conditions, consideration must be given to the space requirements for machine billing. Investment for additional office space should not be required. Consideration should also be given to the number of available personnel. Is the present office force trained so that it can operate the mechanized equipment, or will new people be needed?

Equipment, Forms, and Personnel

When the basic information has been obtained, the sales departments of the companies manufacturing billing and office machinery should be consulted to determine the type of equipment that will best meet the needs of the utility. Information on the size of the job originally determined is very important at this time, for the tendency of salesmen is to recommend a machine that will more than do the job outlined, and one that will also cost more. With the information on available equipment most nearly meeting the needs of the utility, it is possible to produce a set of specifications covering the details listed during the preliminary investigation for submitting bids and quotations. With the exact price of equipment available, a recheck should be made on the space requirements, size of equipment, and speed of operation. A very great part of the total cost picture is contained in requirements for new forms, the possible need for duplicate units in the event of breakdown, repair service for the machinery, and the availability of service. In many of the smaller communities, these considerations can be very important to the final decision on whether to purchase equipment. A billing machine is a very delicate and fine piece of equipment that requires specialized attention whenever it is out of operating condition. Where service has to come from a distant point, very serious interruptions in billing operation may occur while the utility waits for the serviceman.

The cost of new forms is sometimes substantial. The equipment manufacturer should be consulted about forms before the print order is sent in. The size of the form and the position of lines must be definitely set to fit the machine purchased. Because printing takes time, orders for forms should be issued at the same time as the order for the machine.

In scheduling the changeover to machine billing, it is advisable to provide in the schedule sufficient time for training office personnel in the proper operation of the new equipment. It is most helpful if a gradual changeover from the old system to the new system can be arranged.

Multiple Use of Equipment

In all applications of machine billing, consideration should be given to the

possibility of multiple use of the billing equipment. As the original investment is usually sizable, in many instances the same machine can be used for general bookkeeping. Other uses can also be found to provide an even flow of work for the money invested in the equipment. As an example of this type of multiple use, an article published in the *American City*[1] called attention to the use of a modified adding machine for the production of postcard water bills from a three-form unit. This machine permits the postcard to be mailed to the customer and provides two additional forms for office records.

In utilities requiring more elaborate equipment to turn out the total billing job, it is often possible, with the use of interchangeable operating bars, to place the general accounting program on the same machine that is used for billing. In this application, great attention must be given to form design.

Office Efficiency

Utility managers can no longer afford less efficiency in office procedures than in operating procedures. Methods become obsolete in the office as fast as, or even faster than, they do in operations. Because the public so often receives an impression of the utility from its office operation, every manager should give it his full attention. Old hand methods are no longer permissible in today's operations. Salaries are too high to have the efforts of workers wasted. Many of the machine billing operations that have been used in past years should be rechecked and revised. Management must consider office efficiency an important part of overall operating responsibility.

Consultants

It may often be advisable to use the services of outside consultants in choosing the proper equipment. This is comparable to using the services of consulting engineers for sizable improvements in design in other fields of operation. There are many excellent firms that specialize in machine billing surveys, and they can often save the utility a great deal of effort in completing the investigations required. In any event, the foregoing procedures are sound and should not be disregarded just because they seem to be in a field foreign to the usual engineering problems. No utility that has used machine billing would ever think of returning to the old-time methods of operation.

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Taste and Odor Problems in New Reservoirs in Wooded Areas

E. Jerry Allen

A paper presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla., by E. Jerry Allen, Asst. Supt., Water Dept., Seattle, Wash.

MAN'S earliest tests for water quality were those of taste, odor, and appearance. It is interesting to note an early criterion for water quality stated in 1798 by a New York physician, Joseph Brown [1]: "Water . . . that is clear and from a running source, that boils leguminous vegetables tender, in which soap readily dissolves, and [which] has no bad flavor, may be pronounced good water." Although primitive, such tests are not irrelevant—even today.

In the early days of water supply history the sources of tastes and odors were not too well understood, as evidenced by a report of the Cochituate Water Board of Boston in 1854. As a result of numerous complaints that water tasted like fish to some people and like cucumbers to others, Charles T. Jackson, a chemist, and Horsford, a Harvard professor, were retained to determine the cause.[1] Jackson's report stated, "We have proved the peculiar taste of water . . . exists at the fountainhead and that it is not the result of animal putrifaction but of vegetable fermentation. . . ."

Horsford attributed the bad taste to "extracts, more or less volatile, from the decaying minute aquatic organisms, for the most part vegetable, which have been produced in extraordinary quantity upon the low marshes, bogs, and peat lands which supply the surface drainage."

Problems in Reservoirs

New storage reservoirs always present the potential of taste and odor problems. Reservoirs in wooded areas are subject to the effects of decaying organic material, improvements created by man, and the presence of animals.

The consulting engineer's report [2] on Seattle's primary impoundment, Morse Lake (formerly called Cedar Lake), in 1906 states:

> I do not doubt that the water from Cedar Lake, with its many slowly decaying trees, stumps, logs, and weeds is improved as it tumbles over its steep course of 10 mi to the intake. . . . Bad odors from decaying organic or vegetable materials are shaken out, and oxidation is promoted by water running over such a course.

Further in the report reference is made to another source of taste, odor, and quality problems, Swan Lake (now called Lake Youngs), an intermediate storage of 3.5 bil gal which is reported to have been found to have swampy areas that harbored wildfowl at its upper end. Taste and odor problems

arose not only from swampy areas and the presence of wildfowl, but directly from a partial remedial measure. The offending shallow areas were diked off and left in their original state. In order to prevent failure of the dikes as the water level on the lake side was lowered, however, sections of large pipe were installed through the dikes to relieve the hydraulic pressure on the other side, thus allowing the decaying swampy material to drain into the reservoir. Eventually this problem was corrected by removing the pipe, filling the gaps in the dike, sloping the berm away from the impoundment, filling the swamp areas, and installing a clay tile drain around the impoundment to intercept all surface drainage.

As a result of the remedial measures, water quality in the 3½-bil gal reservoir was almost identical to that of water supplied from the river.

Wooded Areas

Deciduous trees adjacent to wooded-area reservoirs, although they create a desirable environment for fish, are detrimental to water quality and a source of taste and odor problems. Hoak [3] reports that, in discussions of tastes and odors in drinking water with seventeen western state health departments, it was agreed that decay of vegetation was the principal cause of bad-tasting water. Not only does decay of fallen leaves create a source of food for algae, but recent investigations of the by-products generated by the decay of leaves show a startling increase in the production of phenols from such decay.

The presence of deciduous trees may be accompanied by the activities of the beaver, which create an adverse bacteriologic condition for drinking water and create small, relatively shallow impoundments with a resultant rise in water temperature. Beavers drag vegetable material into the water, and the shallow areas support the growth of water weeds, which inevitably decay. The effects of beaver activity are increased color, increased bacterial contamination, and an increase in tastes and odors.[4]

Flentje has stated that aquatic weeds may be a source of taste and odor problems when the weeds die and decay and that weeds offer locations conducive to algal growth.[5]

In a 1924 report [6] on forestry practices in Seattle's Cedar River watershed, the following comment is made concerning foliage:

> The heavy growth of alders around the edges of the lakes and watercourses produces a condition that is unsatisfactory. The leaves discolor the water and impart unpleasant taste when accumulated in sufficient quantities. In addition to this objectionable feature, alder is very subject to leaf worm attacks, which, because of their great number, cover the ground with filthy offal. It is advisable that alders as well as other deciduous species within 100 to 150 ft of impoundments be removed and the area planted with conifers.

Improper cutting of trees and vegetative covering in close proximity to the shores of a reservoir can also have an adverse effect on water quality. Erosion carries the finer particles of organic material in the soil into the reservoir, causing decay and odors, as well as providing food material for algae.

Logging operations within the timbered drainage area for a storage reservoir require well supervised road construction. The heavy truckloads of logs require well maintained roads,

roads that are properly ditched and drained. Shallow water, which collects in drainage ditches from the cuts and from the surface of the road, provides an environment conducive to algae growth. It then only requires a good, heavy rain to carry the algae into the reservoir, seeding it for later growth.

In Seattle's primary storage at Morse Lake, copper sulfate treatment is used to check the growth of algae in roadside ditches, small tributary streams entering the impoundment, and shallow areas of the stream leaving the impoundment. The natural aeration that occurs in the river between the lake and the intake also helps to destroy taste and odor.

New Reservoirs

An investigation of possible taste and odor problems arising from domestic water impoundments constructed in the Pacific Northwest within the past 5 years disclosed the presence of tastes and odors in one reservoir during the late summer and fall months. In preparation of the impounding basin, stumps were cut "near" the ground level and only the surface of the basin was cleared. There are patches of mud and decayed vegetation in some of the swampy portions. Work is now in progress to clean up those areas, in order to achieve a more rapid solution to taste and odor problems.

The flooding of new reservoir areas results in the killing of vegetation, decomposition and leaching of the top soil, and release of nutritive materials to the water, thus causing algae and other microscopic organisms to flourish. The normal rate of decomposition of putrescible substances is such that it takes 10–15 years for substantial stabilization of water in the impoundment. The rate of improvement is approximately 14 per cent annually.[7]

The Greater Vancouver, B.C., Water District has had no taste and odor problem from the Capilano Basin reservoir, which was put into service in June 1955.[8] The submerged area was cleared of timber to the high-water line and the stumps were grubbed out as well. There was, however, at the time of flooding, a secondary growth of herbaceous plants over the greater part of the reservoir floor. Approximately 6 months elapsed from the time the basin began to fill until the impounded water was used. There have been some stagnation periods, with a definite effect on the dissolved oxygen content at the bottom of the reservoir.

During the fall of the first year of use, the bottom water was 42 per cent saturated with dissolved oxygen; at the end of the winter stagnation period (March of the following year), the water was 28 per cent saturated. A year later the bottom water was only 10 per cent saturated, and little or no stagnation has occurred in subsequent years. Coincidental with the depletion of dissolved oxygen, there was a marked increase in iron content (3.2 ppm) and manganese content (0.42 ppm). The bottom outlet works of the dam were opened and the bottom water was blown off to waste before the spring turnover. No taste or odor problem arose.

In the preparation of the Capilano reservoir site, close cutting of existing timber in an area of approximately 180 acres was specified, and in no case were the stumps to be more than 12 in. above the ground on the uphill side. A total of 370 acres within the reservoir site was cleared and grubbed; grubbing consisted of complete removal and dis-

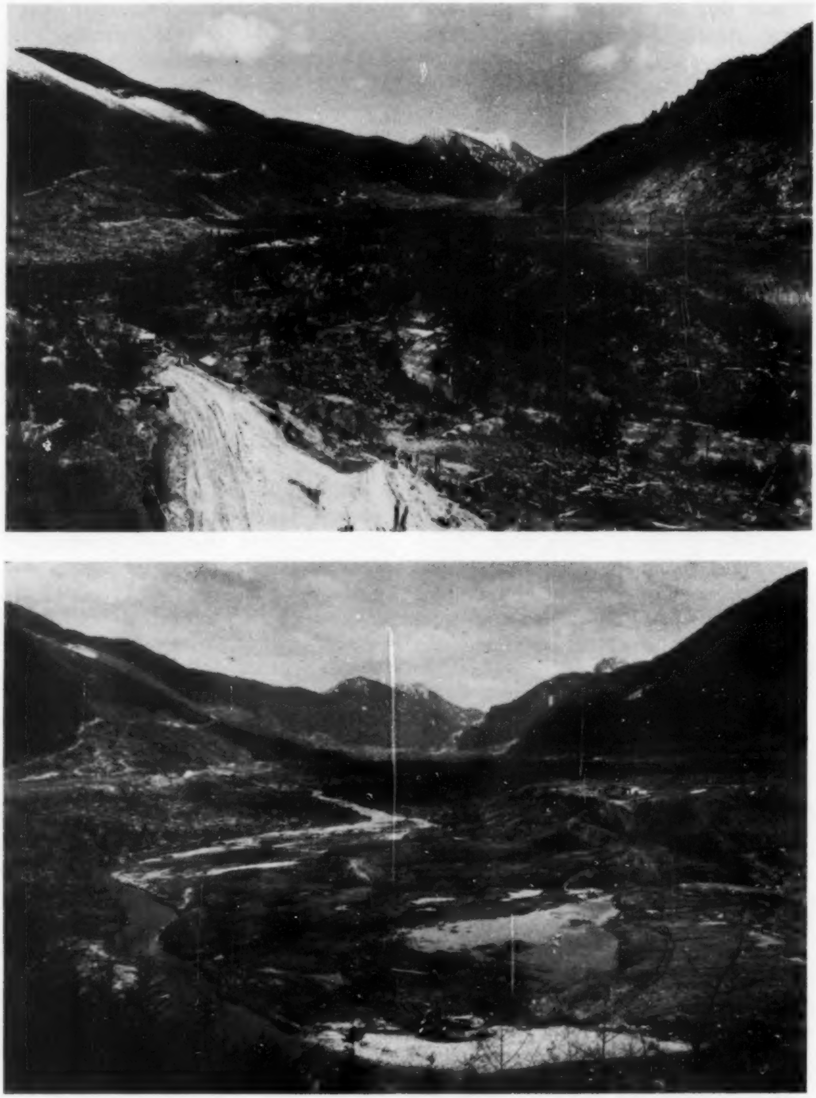

Fig. 1. South Fork of Tolt River Basin Before and After Completion of Clearing and Grubbing

The area shown is just upstream of the dam site.

posal of all stumps, roots, logs, brush, and other woody growths by burning.

It was considered more economical to remove floats of fine material 4 in. or less in diameter, and less than 4 ft in length, by skimming the float from the lake after the basin was filled.

One of the interesting items reported in Patrick's letter [8] stated that in the preparation of an impounding basin behind the new Seymour Falls Dam, burning of debris was in progress during the rainy season of the year. Rain carried the distilled phenols from the burning of alder slash into the water. A strong medicinal taste was found in the chlorinated water. Subsequently, careful control of the periods of burning has eliminated this problem.

The effectiveness of carefully planned clearing and grubbing to prevent taste and odor problems in large reservoirs in forested areas appears to be finding wide recognition. Little Rock, Ark., in preparation of the reservoir site of the Big Maumelle project, required that all trees, stumps, brush, vines, and any other vegetation more than 6 in. in height be removed and that all combustible material, such as timber, logs, snags, uprooted trees, partially buried trees, driftwood, and similar material be cleared, piled, and burned or otherwise disposed of. It was required that all stumps be cut flush with the ground, regardless of slope, and, of course, that all buildings, garbage, scrap material, or barnyard refuse be removed; in other words, everything that could cause contamination or create an environment conducive to the growth of microorganisms was to be removed from the area.

Tolt River Project

The city of Seattle, in its preparation of an impounding basin for the new Tolt River water supply, called for bids on both clearing and grubbing and on clearing only. Because of the exceptionally fine bid received on clearing and grubbing, it was decided to award a single contract.

Following are the very concise specifications relating to the clearing and grubbing of the Tolt Reservoir basin (Fig. 1):

Clearing and grubbing of the areas specified shall consist of the removal and disposal, by burning or otherwise, of all trees, brush, snags, vegetation, refuse or debris left from logging operations, all combustible material, or material which will float when submerged in water and the removal and disposal of all stumps and roots to a depth of 1 ft below the final surface of the ground.

The work shall also include the smoothing over or leveling of holes, depressions or piles of earth left after removal of stumps.

Small roots less than 2 in. in diameter projecting from the ground after smoothing operations may be left, providing one end is fixed in the ground and the exposed portion is less than 3 ft long.

Disposal of Material

Material disposed of by burning shall be burned so thoroughly that the materials are reduced to ashes. No charred pieces shall be permitted to remain.

Burying of stumps, or charred remainders of stumps, within the reservoir basin will not be allowed.

Dumping of material of any nature into the river will not be allowed.

Specifications for the area to be cleared only, below an elevation of 1,660 ft, require the removal of and disposal of all surface materials mentioned under clearing and grubbing, except that standing trees, stumps, and snags are to be cut no higher than 1 ft

above the ground and parallel to the slope of the ground.

These specifications provided for the clearing of the entire reservoir basin below 1,660 ft and for clearing and grubbing between 1,660 and 1,770 ft. The total area involved is approximately 1,100 acres.

Conclusion

Taste and odor problems in new reservoirs in wooded areas can, in large measure, be avoided by recognition of the environmental conditions conducive to the production of tastes and odors and by taking the proper commonsense measures to eliminate such conditions.

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Cold-Water Corrosion of Copper Tubing

Task Group Report

A report of Task Group 2690 P—Cold-Water Corrosion of Copper, presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla., by Kenneth E. Shull (Chairman), Vice-Pres. of Research, Philadelphia Suburban Water Co., Bryn Mawr, Pa. Other members of the task group were R. J. Becker, T. E. Larson, A. A. Minkus, Lee Streicher, D. B. Williams, and A. I. Heim.

COPPER was probably the first metal ever used, because it occurs in the native state and because many of its ores are readily reduced to the metal. Today, copper is used extensively for cold-water service lines. This was shown by an AWWA survey reported in 1952.[1] In 210 questionnaires returned by water utilities in the United States—30 privately owned, 11 authority or district owned, and 169 municipally owned—51 per cent of the utilities said that they used only copper for service lines; another 40 per cent said that copper was one of the materials used.

Problems With Copper

Of the several materials available for service lines, copper has been highly regarded, because it is flexible, easy to install, has a low resistance to the flow of water, and is considered to be fairly resistant to the action of most waters. Unfortunately, however, as many people have discovered, certain aggressive waters attack copper tubing and bring about a number of annoying problems. These have been described in the literature, which includes an excellent review by Ungar.[2] Some of the problems are:

1. Small concentrations of copper cause the formation of blue or blue-green stains on porcelain fixtures.
2. Concentrations of copper greater than 1.0 ppm react with soap to produce insoluble green "curds."
3. A bitter, unpalatable taste results from copper when it is present in concentrations greater than 1.0–1.5 ppm.
4. Small amounts of copper spoil the taste of kola beverages as well as tea.
5. Traces of copper accelerate the corrosion of galvanized hot-water tanks and cause pitting of aluminum pots and pans.
6. Traces of copper are objectionable in many industries—for example, in those involved in the canning of foods and in those using metallic-plating baths. Small amounts of copper in irrigation water are toxic to sugar beets and barley grown in nutrient solution. A concentration of 2 ppm or more is believed to be toxic to tomatoes.
7. Copper is toxic to fish in concentrations of 0.25–1.0 ppm.
8. Pitting corrosion (the most serious problem) may lead to the failure of copper pipe as a result of pinhole leaks.

1955 Survey

In 1955, after an exchange of correspondence among a number of people who were interested in finding out more about the problems associated with the use of copper for water services, AWWA Task Group 2690 P—Cold-Water Corrosion of Copper, was established by the AWWA Water Purification Division. Marshall P. Crabill, now vice-president of operations at the Indianapolis Water Co., became the first chairman of the group.

The objectives of the task group were to: (1) determine how much of a problem exists in cold-water corrosion of copper pipe, and how it affects the water supply industry; (2) find out what information is now available and what studies are in progress; and (3) recommend a program of study, if warranted.

One of the first steps in fulfilling these objectives was the preparation and mailing of a questionnaire to the state sanitary engineer in each of the 48 states. Questionnaires were subsequently sent to privately and municipally owned water utilities in various parts of the United States. A tabulation of the replies returned showed that nineteen of the state sanitary engineers said that problems associated with cold-water corrosion of copper pipe do not exist in their states. Three reported the existence of one or more problems. In one state, Alabama, the problem, primarily one of staining, is said to prevail in eight municipalities with populations of 750–2,000. The problem is confined to waters with pH values of 5.4–6.5 and concentrations of alkalinity of 5–18 ppm. No failures were mentioned.

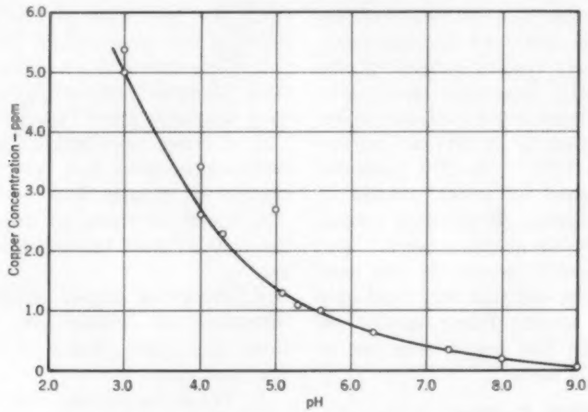

Fig. 1. Effect of pH on Corrosion of Copper

Water at the desired pH was allowed to flow through 60 ft of new 0.75-in. copper tubing at a rate of $\frac{1}{15}$ gpm.

In Maine, the problem is also primarily one of staining, with occasional complaints about bitter taste and nausea. Unfortunately, accurate reports of these conditions are not available. From Nebraska came the report that "any water supply in the state will

pick up copper in varying amounts." Samples taken from copper services, after standing overnight, have been analyzed and residual copper recovered in amounts above the limit of the USPHS standard. A total of 42 questionnaires was returned by water utility superintendents representing 22 states. Of this number, four reported a staining problem, and three reported pipe failures.

Recent Reports

During the last 4 years, additional letters and reports have been received about problems associated with the cold-water corrosion of copper tubing. The reports indicate that the problems are more widespread than had been realized. Hamilton and Flentje,[3] for example, found that many well supplies in southern New Jersey cause copper stains on wash basins and bathtubs. Moreover, they found copper concentrations greater than 0.5 ppm in water from some household taps. In the New Jersey supplies, the staining problem was eliminated in most instances when the pH of the water was increased to 7.0 or more.

In England, Brighton [4] reported that a series of complaints was received about blue water, black kettle scale, green clothes after washing, staining of sinks and baths, and, lastly, nausea after drinking early morning tea. Several samples taken early in the morning showed concentrations of copper as high as 5.5 ppm. Most of the services had been in use for approximately the same length of time—namely, 12–14 months.

In 1958, Williams,[5] at Brantford, Ont., reported that water coming from electric water coolers had a bitter, metallic taste, and that coffee and kola beverages coming from automatic dispensing machines often were unpalatable. Similar conditions have been reported by others. The culprit in each instance was found to be copper.

Experimental Studies

In 1955, some experimental work was done in the laboratories of the Philadelphia Suburban Water Co., Bryn Mawr, Pa., to find out the effect of pH on the corrosion of copper tubing. Water at the desired pH value was allowed to flow through 60 ft of new 0.75-in. copper tubing at a rate of $\frac{1}{15}$ gpm (0.05 fps). Samples were collected at the end of 1 hr and, again, at the end of 1.25 hr, and the concentration of copper determined. The average of the two values was used in plotting the results for each set of conditions. Figure 1 shows the copper concentration plotted against pH.

In a second experiment, water at the desired pH was allowed to flow through 60 ft of new 0.75-in. copper tubing at the rate of 0.5 gpm (0.37 fps) for 1 hr. The flow was then stopped, and the water was allowed to remain in the tubing for 16 hr to simulate overnight conditions. At the end of that time, the flow was again started, with the water at the initial pH and rate. Samples were collected immediately and at various time intervals, and the copper concentration determined. The results of these tests (Fig. 2) show that water with a pH of 4.8 had an immediate copper concentration of 8.2 ppm and required 50 min of flushing to reach a concentration of 0.1 ppm. To reach this same concentration of copper, water with a pH of 6.0 and an immediate copper concentration of 2.9 ppm required 18 min of flushing; water with a pH of 7.0 and an immediate copper concentration of 1.4 ppm required 12 min;

and water with a pH of 9.0 and an immediate copper concentration of 0.2 ppm required 2 min.

It is evident from these experiments and others that the carbon dioxide content of a water—indirectly measured by the pH—has a very significant effect on the solubility of copper. In most instances, increasing the pH of the water to a value greater than 7.0 greatly minimizes this action.

1957 Survey

In order to determine the service record of copper tubing in different environments, a survey was started in 1957 under AWWA direction. During 1957 and 1958, 42 3-ft specimens of copper tubing were collected from fourteen cities situated in various parts of the United States and Canada. All of the specimens were taken from active water services that had been in use for 12–35 years. Except for one specimen, they were all Type K tubing. As much as possible of the history of the environmental conditions was obtained along with each sample. This included: (1) the chemical composition of the water carried by the tubing, (2) the quantity of water carried by the tubing, and (3) the general nature of the soil in which the tubing was located.

Of the 42 specimens collected, 33 were sent to Water Service Laboratories, New York, N.Y., for physical and chemical analysis. The remaining 9 specimens were eliminated, because they were multiple samples from the same city and met all three of these criteria:

1. Both the external and internal appearance of specimens from different addresses in the same city were very similar.

2. Conditions of soil surrounding the pipe specimens were probably the same.

3. The water supplied to each of the addresses was probably the same in composition.

Specifications for the project were established by representatives of AWWA, the Copper & Brass Research Association, and Water Service Laboratories. Financial support was received from the Copper & Brass Research Association. Much of the material that follows was taken from

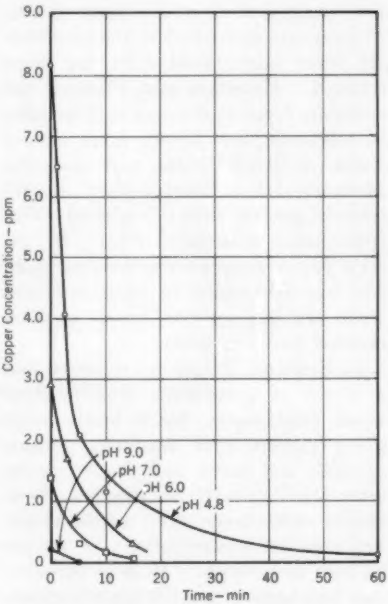

Fig. 2. Effect of Time and pH on Corrosion of Copper

The carbon dioxide content of a water, indirectly measured by the pH, has a very significant effect on the solubility of copper.

the report by the Water Service Laboratories.[6]

Copper Service Study

Each 3-ft specimen was divided into three 1-ft sections. One of these was then split longitudinally into two portions by means of a band saw, and both internal and external surfaces were examined for pitting and general thinning before and after cleaning. The split sections were then carefully tapped to remove any metallic copper cuttings that might have been present as a result of the splitting operation. They were then cleaned with a stiff fiber brush, and the material removed was saved for chemical analysis. Those deposits that could not be removed by brushing were treated according to ASTM procedures,* and a few that were resistant to this treatment were removed by an acid fluoride procedure.

Whenever pits occurred, their frequency, shape, characteristics, average and maximum depths, and position—that is, top or bottom of the tubing—were determined. For the calculation of pit density, the total number of pits on each surface was counted when there was a limited number of pits. With numerous pits, a small area providing a fairly typical distribution of pits was examined, and both the number of pits and the area selected were recorded. The wall thickness of each specimen was measured at three separate cross sections, and the values obtained were compared with official specifications.

The smoothness of the interior surface of each specimen as received was described by such relative terms as rough, reasonably smooth, and smooth. If deposits were present, measurements were made of the area that they covered, as well as of their average and maximum thickness. To complement the description of the color of deposits, photographs were taken and colored slides were prepared of the interior surfaces of all examined specimens before they were cleaned.

Copper tubing has been made to an ASTM standard (B88) for years. Thus, dimensions and weights for tubing are carefully stipulated, and it was possible to compare the standard weight with the weight of a 6-in. section of each specimen after it was cleaned, to determine whether any significant weight loss had occurred. The composition of the interior coating or scale was then determined by qualitative analysis. A semiquantitative analysis, which included such constituents as volatile matter, carbonates, calcium, magnesium, copper, iron, and insolubles, was made in those instances where the scale was found to be heavy. Finally, a 3-in. piece of each sample was sent to the Research Department of Revere Copper & Brass, New York, N.Y., for analysis of the tubing metal.

With few exceptions, the condition of the copper water service tubing examined in this study was excellent. External corrosion did not appear to be a serious factor. Only one specimen (from Santa Monica, Calif.) showed complete perforation from the inside, and only three (from St. Louis, Mo.; Akron, Ohio, and another one from Santa Monica, Calif.) showed internal tubercles or other deposits sufficiently large to interfere significantly with the flow of water. Although the perforated sample from Santa Monica was taken from the downtown area, there were no power facilities for street cars

* ASTM Method B185-43T, Appendix 11D.

or underground power facilities adjacent to it. Thus, it is unlikely that stray currents were involved. As a matter of fact, the service had been in use for 14 years, and it gave no indication of external surface corrosion. Since 1941, the water served to the system came from the Colorado River.

The interior of the tubing, on the other hand, was covered with a rough, tuberculated green deposit. Some tubercles as large as 0.25 in. in height and 0.5 in. in diameter were present. The deposit contained 67 per cent of copper compounds (as copper oxide), and approximately 25 per cent of volatile matter as the second largest constituent. Removal of the deposit revealed an average of eight pits per square inch. The deepest of these had penetrated the tubing wall completely; the average pit had penetrated about one-third of the wall thickness. Despite this damage, the tubing met ASTM standards for average wall thickness and for weight per unit length. Obviously, however, the useful life at this location had been exceeded.

Similar conditions have been reported from Laguna Beach, Calif., which also receives water from the Colorado River. At Laguna Beach, there have been a number of instances of complete failure of Type K copper tubing after 17–18 years of service. Apparently, this was the result of localized corrosion with deep pits developing under an emerald-green deposit of basic copper sulfate. Well defined crystals of red cuprous oxide have been found in the cavities underneath the green basic sulfate scale. Water samples collected from the Laguna Beach distribution system in 1959 contained no more than 1 ppm of free carbon dioxide and less than 0.3 ppm chlorine.

It is interesting to note that Los Angeles, which uses some Colorado River water, also reported a small number of failures after 10–15 years of service. These failures, however, occurred in various sections of the city which were not necessarily supplied with the same type of water. The only other specimen that showed serious pitting was from St. Louis. This was one specimen of three examined from that city. The specimen had been in service for 21 years, and, although the outside was in excellent condition, the inside was covered with a heavy, green, rough deposit that had a thin, tan surface coat. The deposit consisted of elongated tubercles in the form of flaky folds running along the axis of the tubing. The folds had a maximum height of 0.25 in. Approximately 37 per cent of the interior deposit contained copper compounds (as copper oxide) and nearly an equal percentage of acid insolubles.

On removal of the interior deposits, the pipe was found to have thirteen pits per square inch. Many of these had penetrated nearly two-thirds of the wall thickness, or showed an average penetration rate of more than 3 per cent a year. Although wall thickness and weight per unit length met ASTM standards, the pitting rate indicated a probable further service life of approximately 10–12 years. Failure would have certainly occurred had this been Type L copper tubing.

In addition to the two specimens already discussed, one from Akron, Ohio, had an internal buildup of tubercles or corrosion products sufficient to interfere significantly with the flow of

water. This specimen, which had been in service for 26 years, showed an excellent exterior surface. But the interior was completely covered with a rough, nontuberculated, olive-green deposit, approximately one-third of which consisted of acid-insoluble material and 25–30 per cent each of iron oxides and volatile material, including some carbonates. Less than 2 per cent of copper compounds (as copper oxide) were present, which indicated that the deposit came largely from external sources and not from corrosion of the copper tubing.

After 26 years of service, a specimen from Detroit, Mich., showed both internal and external pitting. The outside showed an average of approximately 43 pits per square inch, with a maximum depth corresponding to 3 per cent of the wall thickness. The interior surface had an unusual speckled appearance, with approximately 10 per cent of the surface covered with copper that was still bright and the other 90 per cent covered with a brown oxide coating containing green and red tubercles. The largest of these was approximately $\frac{1}{16}$ in. in height and diameter. Removal of the coating revealed an average of about 25 pits per square inch, with the deepest pit approximately 16 per cent of the wall thickness.

Chemical analysis showed that approximately 72 per cent of the internal deposit was made up of copper compounds (as copper oxide). Iron oxide was the second largest ingredient, with approximately 10 per cent present. The average wall thickness of this specimen was slightly less than that specified in the ASTM standard, as was the weight per unit length. Despite the thinning of the wall, the specimen probably had not exceeded a quarter of its useful life at this location. Most of the remaining specimens showed excellent conditions, with thin, smooth, interior surfaces.

Corrosion Factors

The fact that this survey disclosed a number of instances in which different samples, which had been in service on the same water supply, showed significantly different degrees of corrosion on the inside of the tubing, indicates that water composition is not the only factor in corrosion of copper water service tubing. In a further attempt to explore the possibility of a relationship between the water composition and the condition of the tubing, calculations were made from the average water analyses with the use of the Langelier index, Ryznar stability index, and the corrosion index suggested in an article by Riddick.[7] None of these showed a significant correlation with the observed pitting or thinning of the copper tubing specimens. Therefore, although the composition of the water—especially its carbon dioxide and oxygen content, and, to a lesser degree, the content of ammonia, iron, manganese, and chlorine—is an important factor in the corrosion of copper tubing, the composition of the tubing, the way it is installed, stray currents, velocity of water flow, and a condition reported by H. S. Campbell[8] of the British Non-Ferrous Metals Research Association must be taken into account. Campbell and his associates found that, in England, practically every failure of copper tubing in hard or moderately hard water could be traced to a film of carbon that developed during annealing of the pipe and that acted as a

cathode. In the same article, these investigators reported the significant fact that some waters contain organic substances that inhibit the corrosion of copper. Not yet identified, these substances appear to be negatively charged organic colloids. They are removed by treatment with activated carbon but are not destroyed by moderate heat.

There does not seem to be any strong correlation between the amount of copper in the interior deposits and the condition of the tubing. Nor does there seem to be any correlation between the condition of the tubing and the chemical composition of the tubing metal.

Conclusions and Summary

From the information gathered and reported in this article, it is evident that copper is a very desirable material for use as a conveyor of cold water. Copper will continue to be used extensively for cold-water services. It must be recognized, however, that there will be problems associated with the use of copper when the water it carries is soft and of low pH, when stray currents are present, when flow rates are high, or when the tubing is of poor quality.

Most important of the problems associated with the use of copper are: staining; metallic taste, especially in the water first drawn in the morning, and the occasional nausea that follows its use; the pitting of galvanized hot-water tanks; and perforation of the tubing. Although the latter problem apparently occurs to a limited extent, it is quite annoying to consumers and to water utility operators who must deal with it.

The report from Water Service Laboratories [6] indicates that the useful life of most of the specimens examined is more than 200 years. Because of this estimate, it is reasonable to assume that if Type L tubing had been used in these installations it, too, would have given satisfactory service. It would then seem that serious consideration ought to be given to the use of Type L tubing, except in those areas where copper tubing is known to fail in a comparatively short time. This consideration is based on chemical results only and not on properties pertaining to mechanical handling and other factors.

The entire question will be reviewed and studied by an AWWA committee soon to be established, and it is hoped that, following its investigation, the committee will make a definite recommendation.

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Experience With Main Breaks in Four Large Cities

Panel Discussion

A Panel Discussion presented on May 17, 1960, at the Annual Conference, Bal Harbour, Fla.

Philadelphia—*Gerald E. Arnold*

A paper presented by Gerald E. Arnold, Gen. Supt., Water Dept., Philadelphia, Pa.

PHILADELPHIA has one of the oldest large water systems in the United States. The first part of the system was built in 1799, with wooden mains. Beginning in 1819, cast-iron pipe was laid, and by 1850 all of the wooden mains had been abandoned. The more than 3,000 mi of pipe within the city limits varies in age from a few months to more than 130 years. Main breaks occur frequently in a system of this size and age. As many as 1,000 breaks have been recorded in a single year, with a maximum of 300 a month during the colder months. Breaks have occurred in all sizes of pipe, from 3 in. to 48 in., at various locations in the city, at different pressure levels, and under varying conditions of traffic and other external forces.

Temperature Changes

The majority of water main breaks in Philadelphia occur during the three coldest months of the year, January, February, and December. During this period the water temperature reaches its lowest point of the year. The temperature at the intakes from the rivers is generally close to 32°F, and the temperature throughout the system seldom rises above 35°F during the winter months. Frost penetration in Philadelphia varies from 12 in. to 30 in., depending on the duration and severity of the cold weather. It has been noted that the greatest number of breaks usually occurs at the time of the winter when the temperature is dropping most rapidly for the first time. It is believed that the sudden chilling of the water and the surrounding earth results in shrinkage of the pipe metal, thus setting up sufficient longitudinal stresses actually to pull the metal in two at points where it has already weakened. The majority of the breaks found under these conditions are circumferential cracks, with little longitudinal deviation. Most of these breaks can be repaired by installing a split clamp around the crack. Some cracks of this type occur at other times of the year, but those are believed to be due to beam action from blocking under the pipe or to other external forces.

An unusual occurrence during April 1960 is worthy of note. The month

of March 1960 was one of the coldest of record, and April was one of the warmest of record, temperatures exceeding 90°F on several occasions, which is unusual for Philadelphia in April. During April 1960, there were 50 water main breaks, compared to 23 for April 1959. The 1960 record temperature was 30 per cent above the average for that month. It is believed that these breaks were occasioned by rapid and unusual temperature rises.

Pressure Changes

Changing pressures in water systems can cause main breaks, particularly if those pressure changes are sudden, such as those associated with water hammer or rapid changes in operating pressures. A number of years ago, a pressure change was made in part of the Philadelphia distribution system which raised the pressure only about 10 psi but resulted in eighteen main breaks in a single hour. The points at which the mains broke with this slight pressure change were already weakened by some other cause. The author had an experience a number of years ago with another water system in which day and night pressures varied as much as 100 psi owing to unfavorable operating conditions. This resulted in some serious breaks in a 16-in. supply line.

Supporting Ground

Another common cause for water main breaks is shifting or settling ground. Pipe that is normally supported throughout its length should be subjected to few bending strains. If the ground shifts or settles unevenly the transmittal of beam forces to the pipeline can set up strains that exceed the tensile strength of the metal.

Serious difficulty has frequently been encountered with a 48-in. line on Broad St. in Philadelphia, where the line is carried on concrete piers over the top of a subway. Uneven settlement of these piers has resulted in a distortion of the pipe, transmitting unusual stress to the metal. Frequent breaks have occurred in this line, and, in some instances, it has been found that the pipe was not resting on the piers, which would normally support it from below, either at the point of break or at an adjacent pier. Surveys of this pipeline have indicated wide deviations from a straight alignment. Most of the breaks have been at the bell with a circular crack running one-half or two-thirds of the length of the joint and returning again to the bell, with the result that a large segment of the pipe is broken away completely. This pipeline is also subject to vibration of traffic from above and subway trains from below. In addition to breaks in the pipe itself, there have been frequent joint leaks, indicating that the pipe is moving.

Electrolysis

Another detrimental action that weakens pipe metal is soil corrosion, or stray-current electrolysis. Corrosive soils or stray currents tend to eat away the metal from the outside of the pipe, usually in concentrated locations, thus producing a thin wall or complete breakthrough in small areas. Removal of metal from the pipe wall, of course, also weakens the wall so that any unusual strain may result in a break. The problem of stray-current electrolysis is becoming increasingly serious in cities where there has been a partial abandonment of the streetcar system. Often the abandoned tracks, when they are no longer used for streetcars, are paved over and used as a return path for the current supplying operating tracks. These old rails,

being paved over, are not properly maintained, and open joints frequently develop resulting in discharge of large quantities of current to the ground and underground structures, such as pipelines. When one recalls that 1 amp of current will remove 20 lb of metal in a single year, there is a definite reason for concern when as much as 600 amp is found traveling on an underground piping system.

Traffic

Traffic conditions have materially changed in recent years. When many of the pipelines were laid 50–100 years ago, street traffic consisted of horse-drawn vehicles. Today, modern motor trucks, weighing as much as 30 tons, pound the depressions in streets and transmit shock waves to all underground structures. The standard practice in Philadelphia has been to bury water pipe with at least 4 ft of cover. In the old days, this was sufficient, but with modern traffic loads it is felt that more cover should be provided or that there should be a very heavy concrete base under the pavement to take the impact of traffic shock. It has been noted some main breaks have followed the development of chuck holes in the street where heavy trucks pounded into these holes, setting up noticeable vibrations.

Age of Pipe

Extreme age does not necessarily indicate poor condition of pipe. Many miles of pipeline in the Philadelphia system are more than 100 years old and are still rendering satisfactory service with comparatively few breaks, whereas other pipe 50–75 years of age has had more frequent breaks.

A study of the pipe removed from the system indicates that there is very little weakening of the metal due to internal corrosion. Tuberculation of the interior surface is evident, but pitting of the metal is negligible. External forces or corrosion factors are much more important than internal corrosion. A study of pipe removed after many years of service indicates that wall thicknesses are materially reduced from the outside. In most instances metal has been removed in spots, leaving noticeable cavities and a few fairly extensive areas of thin metal.

Construction and Operation

Good construction is the best way to avoid water main breaks. A study of breaks in Philadelphia has led the author to believe that much of the trouble was occasioned by improper construction methods. Blocking was utilized in Philadelphia for many years, and it is the author's firm conviction that this was responsible for many breaks. Blocking should be prohibited. The standard practice in Philadelphia now is to encase the new main in 6 in. of clean sand. The trench is excavated to 6 in. below the bottom of the pipe and backfilled with sand; the pipe is firmly bedded in the sand, and, after the joints have been made, sand is placed around the pipe to a full thickness of 6 in. The balance of the trench is then filled with exacavated material, excluding broken concrete, stone, or other debris. The backfill is thoroughly tamped in thin layers to the surface of the ground and then allowed to settle and become thoroughly compacted before paving is placed. To lessen the shock of traffic impact, a base course at least 6 in. thick should be made of poured concrete and topped off with asphalt or some other finish coat. Excavations for repairs and maintenance work should be backfilled in the same manner.

All pipe should be thoroughly inspected at the plant and again on the job site before installation. Old records of the Philadelphia Water Department indicate that pipe inspected on the job 50–60 years ago was subject to about 20 per cent rejects. Manufacturing is probably much better today than it was at that time, but piping is still subject to damage after it leaves the factory and before it is installed. Tests at pressures at least 50 per cent higher than normal working pressure should be made before the line is accepted from the contractor.

Cities having surface streetcars should make a study of the electrolysis problem, particularly if some of the streetcar lines have been abondoned and the rails are still in place and used for negative return current. Continuing electrolysis studies should be made to see that the water system is not being damaged by stray currents. Soil surveys should be made in advance of construction to determine whether or not special protection is necessary to prolong the life of the new pipeline. The installation of rectifiers, insulating, or bonded joints may be highly desirable, and their cost is but a fraction of the cost of replacing a pipeline.

Care should be exercised to avoid frequent wide fluctuations in pressure. A pipeline carrying water at pressures varying as much as 50–100 psi actually deflects with the pressure changes, and metal fatigue may result in serious breaks. Whenever a break occurs, a study of the attendant conditions should be made before the trench is backfilled. This will enable the operators to ascertain to some degree the cause of the break and assist in designing to avoid repetition of the failure in the future. In some instances breaks take place for no apparent reason. On several occasions the author has seen cast-iron lines in which a section of the pipe broke out on one side or the bottom in the middle of a joint without cracking the bell or the spigot. The metal surrounding the break appeared to be sound and there were no unusual operating conditions that could account for the break.

Flexibility at the joints is another factor which, it is believed, can reduce the number of breaks. With the new type of rubber ring gasket, there is much more flexibility than there was in older types of joints. Movement at the joint relieves stress in the metal and should be helpful in reducing the number of breaks.

Conclusion

Water main breaks usually occur at a point where the metal has been weakened by corrosion or some other cause, but the actual breaking of the metal occurs as a result of some unusual external force such as temperature changes, shifting ground, foreign objects, or traffic impact. Weakening of the metal is a result of age, but age is not necessarily the most important factor. Once the metal is weakened, an unusual strain may result in a fracture of the metal. In the author's opinion, sudden temperature changes are responsible for most breaks, although other factors may be involved. Water main breaks should be studied as they occur by a qualified engineer, to determine, if possible, what caused them. By studying this information and following good construction practices, many of the water main breaks experienced in the past can be avoided in the future.

New York—*Edward J. Clark*

A paper presented by Edward J. Clark, Chief Engr., Bureau of Water Supply, Dept. of Water Supply, Gas & Electricity, New York, N.Y.

Water main breaks have always presented considerable problems to water supply engineers, not only because they disrupt the supply and are expensive, but also because of damage caused by the flooding of subways and basements, the upheaving of pavements, interference with vehicular traffic and transit service, and other inconveniences suffered by the public.

Causes of Breaks

Breaks in cast-iron mains may be caused by flaws in pipe and castings; internal pressure in excess of that for which the pipe was designed; deterioration of metal due to corrosion; electrolysis; freezing of exposed pipe; excessive earth load due to depth of cover over pipe; unbalanced pressures in the line such as at bends and caps; unequal settlement of the soil in which the main is laid; settlement of other subsurface structures crossing the water pipe, such as electric conduits or gas and steam mains; vibrations due to blasting in close proximity to the main; and other causes.

In the New York system, the number of breaks due to defective pipe and castings, excessive internal pressure, deterioration of metal, electrolysis, or freezing is negligible. Many water main breaks have been caused by settling of the main over short stretches. This causes the pipe to act as a beam, for which it is not designed, and results in fractures or loose joints. Settling of a water main over short stretches may be caused by improper bedding or by the gradual wearing away of soil under the main as a result of a small leak from a pipe joint.

A substantial number of breaks in New York has been caused by unequal settlement of water mains along subway routes and the settlement of subsurface structures, such as electrical conduits or gas and steam mains, crossing the water pipe and resting on it.

It is sometimes difficult, if not impossible, to determine the exact cause of a specific break, as the subsurface conditions existing when the broken main is exposed may be entirely different from those prior to the break. There is no way of knowing what the prior conditions were.

The New York distribution system comprises about 5,800 mi of mains incorporating some 4,000,000 pipe joints, 450,000 pipe fittings, 165,000 gate valves, and 90,000 hydrants. For the past 10 years, there has been an average of 330 breaks each year (almost one a day), 20 of which have been in 20-in. pipe and larger, with the majority in the 6–8-in. sizes. Although there is no specific pattern as to time of day breaks occur, it appears that many of them take place during the early morning hours. This may be due to the sudden opening of existing splits in the pipe as a result of slight increases in internal pressures during the early morning hours when the water demands are low.

Preventive Measures

The steps that have been taken to minimize breaks include improved construction methods and strict inspection

of materials and installations. The use of steel pipe for all mains larger than 20 in. has been standard practice in New York for the past 30 years.

Specifications for water main installations require:

1. Well tamped bedding of clean earth or sand under, around, and over the pipe
2. Consolidated backfill to distribute the traffic loads
3. Installation below the frost line to prevent heaving
4. Use of rods on bends and fittings to help the pipe withstand unbalanced pressures
5. Proper assembly and calking of lead joints to prevent leaks
6. Hydrostatic field testing of pipe (All mains 20 in. or larger are subjected to hydrostatic field tests at 125 psi, and in certain other cases, such as bridge crossings, similar tests are required on mains smaller than 20 in.)
7. Reinforced-concrete mat, with cradles or pile supports, in areas of fresh fill, swamps, and other places where the bearing capacity of the soil is poor
8. Concrete cradles under the pipe in rock trenches.

In an effort to reduce the number of leaks and breaks, an inspection force is maintained at the foundries where the pipe and castings are made, to make sure that the materials are sound and are being manufactured in accordance with specifications. Also, all water main installations have competent inspectional supervision to insure the strict enforcement of all contract specifications. The water department also has a special force engaged in systematic surveys to detect and eliminate underground leaks. Such leaks, which do not appear at the surface, may cause the gradual erosion of soil under the main and thereby result in unequal settling of the pipe and possible rupture. Approximately 600 leaks from joints, split pipe, taps, services, and gate valves are detected yearly, thus effecting an average saving of 25 mgd.

As mentioned before, the use of steel pipe for mains larger than 20 in. is another safeguard adopted to curtail breaks in large mains and thereby reduce flood damages, disruption of traffic, and other inconveniences. To minimize the effects of electrolysis on steel pipe, insulating joints are installed in the line, and, in some cases, cathodic protection is provided.

Remedial Action

New York has had many breaks in large mains which have resulted in a great deal of flooding and disruption of subway traffic.

When breaks do occur, the first action taken is to shut down the feeds to the main in the shortest possible time in order to minimize damages. For this purpose, emergency crews are maintained on a 24-hr basis and have trucks equipped with motorized valve-operating devices as well as short-wave radios to speed up operations.

Narrows Siphon Incident

Perhaps the most serious break, and certainly the most difficult one to repair, was the break in a 36-in. cast-iron submarine pipeline crossing the narrows in New York Bay and supplying the Borough of Richmond with water. The nature of the pipe fracture indicated that it was caused by one of the spuds of a large dredge which had been working directly over the pipeline at the time of the break.

When the break occurred, a gage located in one of the pumping stations

recorded a sudden drop in pressure from 70 to 28 psi. Within 15 min, it was determined that the drop in pressure had to have been caused by a break in the narrows siphon, as a venturi meter showed that a large quantity of water was flowing in the pipe at the Brooklyn end, but no water was reaching Richmond. Backflow from Richmond was prevented by a check valve in the pipeline near the waterfront. Within an hour after the break occurred, the Brooklyn end of the line was shut down, stopping the 28-mgd flow that had been wasting into the bay.

Siphon Repairs

Because the narrows siphon furnished more than two-thirds of the supply for Richmond and local sources could not possibly have met the demand once the storage in the distribution reservoir had been consumed, immediate action to effect repairs had to be taken. Under the emergency powers of the commissioner of the department, a dredging company was engaged to examine the line and make repairs. Three hours after the break, the company had some of its plant on the job and started pumping air into the pipeline to locate the leak. After 2 hr, the air began to show at the surface of the water, indicating the break to be about 170 ft from the end of a pier on the Richmond side. At that point the pipe was under 30 ft of water and 20 ft of harbor muck and fill. The contractor started immediately to excavate the material over the pipe by bucketing and pumping. Approximately 4,000 cu yd of material had to be excavated to provide enough space to remove the pipe and effect repairs.

Meanwhile, pumping of local sources in Richmond was increased to the full capacity of the pumping stations. This was not sufficient to meet the demands, however, and 7 mgd had to be drawn from storage in the distribution reservoir in Richmond. The reservoir could supplement the supply from local sources for only about 60 days.

To help alleviate the emergency, steps were taken to stop waste and leakage and the public was apprised of the necessity of conserving water. Pressures were reduced by 13 psi during the day and 17 psi at night. At first, there was a 3-mgd (15 per cent) drop in consumption, but the demand gradually increased as the consumers found that there was no immediate likelihood that the supply would be curtailed.

Within a week after the break occurred, the pipe was uncovered sufficiently to permit the removal of the broken section. In order to permit a diver to enter and make repairs, it was found necessary first to enlarge the hole in the broken pipe. Cutting of the broken section for removal was done mostly from the inside by means of electric torches and was continued night and day until the work was completed and the broken pipe could be brought to the surface. This took 10 days.

While the work of cutting was in progress, designs were made and orders placed for a solid cast-steel sleeve about 5 ft long and for a split sleeve of similar length, it being expected that one of the sleeves could be found suitable to effect repairs. The solid steel sleeve was used.

The muck which had settled in the exposed ends of the pipe upon removal of the broken section was cleaned out by the divers and timber blocking was laid at the bottom of the trench to support the new pipe. The solid steel

sleeve was then placed over the end of the cut pipe. A new length of flexible-joint pipe, which had been turned down to the normal outside diameter at the spigot end, was lowered in place, and the sleeve was drawn over it, closing the gap. The two sleeve joints and the flexible bell joint were then calked with lead wool.

Before the siphon was restored to service it was cleaned by introducing water from the Brooklyn end and discharging through a blowoff at the Richmond end. Chlorine was injected at the Brooklyn shore by means of a temporary connection and chlorination plant in order to disinfect the interior of the pipe, which had been subjected to contamination during repairs from the sewage-laden waters of the bay. The treatment was continued for 7 hr, after which unchlorinated water was passed through the pipeline for 3½ hr. A sample of water taken and examined at the end of this period proved to be of excellent sanitary quality. Tests showed the new joints to be tight.

A month after the break had occurred, the siphon was again in service supplying water to Richmond. Backfilling under, around, and over the main was continued for a week until a depth of about 10 ft over the pipe was secured.

Conclusion

While the siphon was under repair, 200 mil gal was drawn from storage in the Richmond distribution reservoir, depleting it to half of its capacity. Although there was no immediate danger of exhausting the supply in this reservoir, the situation caused considerable uneasiness for a time, and soon after this incident an additional 42-in. pipeline was installed across the narrows.

With duplicate feeds to Richmond, there no longer is much danger of a serious interruption of service to that borough. Contract plans are being prepared presently for constructing a 10-ft water tunnel to Richmond, to take care of the future requirements of the borough, with the population growth expected to be occasioned by the construction of a new bridge connecting it with Brooklyn. When this tunnel is completed, the two mains crossing the narrows will be kept on a standby basis and Richmond will be assured of an unfailing supply of water.

The narrows siphon incident points up the urgent need of installing dual transmission mains to isolated areas so as to assure a supply of water in the event of a break. New York provides such feeds to several islands in the East River on which hospitals and penal institutions are located.

Detroit—Gerald J. Remus

A paper presented by Gerald J. Remus, Gen. Mgr., Dept. of Water Supply, Detroit, Mich.

The Detroit Department of Water Supply provides water for Detroit and 49 adjacent communities, and contract negotiations are underway to provide service to twelve additional communities. At the present time 3,400,000 people, or 42 per cent of the population of Michigan, get their water from the Detroit system. Detroit has three major pumping stations, with the fourth under construction, and plans are already underway for a fifth

major station. Water is transmitted and distributed to the system through a network of steel, asbestos-cement, reinforced-concrete-lined steel cylinder, prestressed-concrete cylinder, and cast-iron pipe, totaling more than 6,600 mi. A breakdown according to type is given in Table 1.

All water service contracts between Detroit and its suburban municipal customers require that installations must meet Detroit's standards in every characteristic. The establishment of these standards requires extreme care and sound engineering judgment. Equally important is the public relations job of winning acceptance and application of these standards. In addition, the annual repair and maintenance expenses, with service reliability, became major factors in the cost of water. Therefore, there is a twofold purpose in studying water transmission and distribution systems: to control costs and reliability, and to guide the development of an ever enlarging, reliable, and efficient water system, involving many units of government.

The Detroit Water Board maintains the mains within the Detroit city limits, and good records are available. The suburban communities maintain their own distribution systems and the Board does not have their records. Therefore, this analysis of water main troubles is concerned only with the 3,085 mi of pipe within the Detroit city limits.

TABLE 1

Types and Lengths of Detroit Area Water Mains, 1960

Type	Installed Length—*mi*		
	Detroit	Suburban	Total
Steel	52	3	55
Asbestos-cement	3	19	22
Reinforced-concrete-lined steel cylinder	52	80	132
Prestressed-concrete cylinder	13	24	37
Cast iron	2,965	3,420	6,385
Total	3,085	3,546	6,631

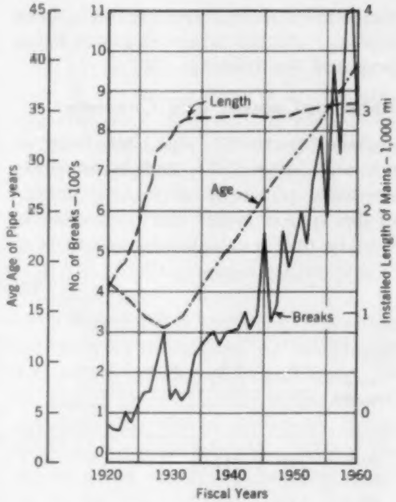


Fig. 1. Cast-Iron Main Breaks in Detroit, 1920–60

Because of the increase in the number of breaks in cast-iron mains (the total miles of main remains relatively constant), Class 150 cast-iron pipe is no longer acceptable in Detroit.

Steel Pipe

The 52 mi of steel pipe have been in service 25–30 years. Most coatings that were used were of insignificant protection, and failures due to corrosion have been in the form of leaks rather than breaks. During the period 1950–59, an average of 46.9 leaks per year has occurred in steel mains. The sizes of the mains in which trouble occurred varied from 12 in. to 60 in. Because there has been an increase in pitting and deterioration of steel pipe,

the smaller sizes have gradually been replaced and the larger sizes are being prepared for relining.

Asbestos-Cement and Concrete

Asbestos-cement pipe has been in use only since 1937, and in moderate amounts. An evaluation of the merits of this type of water carrier can, therefore, be only a calculated guess at best. The performance record of asbestos-cement pipe does indicate, however, that its use will be continued and moderately increased.

Reinforced-concrete and prestressed-concrete water mains, totalling 167 mi of large pipe, have furnished satisfactory service. These mains have not faced the test of time, but the record developed thus far indicates that their use will be continued.

Cast Iron

The bulk of the 3,085 mi of main within the Detroit city limits is cast iron. This pipe has been used since 1838. Of the cast-iron pipe in service, 2,750 mi is largely of Class 150, and 215 mi is Class 250 pipe. Class 250 pipe has not caused trouble, but it has been in use only since 1941, and only in 6- to 24-in. sizes. The record of cast-iron main breaks (practically all in Class 150 pipe) is given in Table 2. The curves in Fig. 1 illustrate the total cast-iron main breaks since 1920, the average age of the pipe, and the number of miles of mains in service. The total main breaks gradually increase, and as the total miles of mains remains relatively constant, the only conclusion that can be arrived at is

TABLE 2

Record of Breaks in Detroit Cast-Iron Water Mains, 1940–60

Year Installed	6 in.	8 in.	10 in.	12 in.	16 in.	24 in.	30 in.	36 in.	42 in.	48 in.	Total
	No. of Breaks										
1940	140	152		9	1	1					303
1941	176	173		8	3	1	1			1	363
1942	147	151		18	6		1				323
1943	169	158	3	8	2	1	1	1	2	1	346
1944	206	175	3	5	3		1		3	1	397
1945	228	204		9	5		1			1	448
1946	133	167		10							310
1947	225	188		16	2	2			2		435
1948	274	275		16	2	2			3		572
1949	227	230	1	17	4	2					481
1950	260	270		9	2	6	1				548
1951	269	243		18	5	2	1				538
1952	296	255	1	13	3	2	1		1	1	573
1953	410	322	2	20	5	1		1		2	763
1954	300	322	1	19	7	1			2		642
1955	342	376	1	23	7	6	1				756
1956	405	356	5	28	4	4	1	1	1		805
1957	357	362	2	2	33	11	1	1	1		770
1958	476	459	1	30	9	4	1				980
1959	479	419	3	44	15	2	2		1	1	966
1960*	217	219		17	3				1	1	458

* Estimated for May and June.

that as time elapses the maintenance of existing mains is going to cost more and more, service of distribution system will become more unreliable, and a replacement program will have to continue.

The causes of breaks in these cast-iron water mains cannot be identified exactly. There are many related variables, such as water and ground temperature changes, thinness of pipe walls, poor construction materials and practices, water hammer, excessive street loads causing street settlement which could be amplified by shock and insufficient thickness of concrete in the roadbed, sewer washouts, inflexible pipe joints, poor soil conditions, and other utility obstructions. All of these factors affect results, but how much each should be held accountable for is hard to evaluate. Water temperature changes and substandard pipe wall thicknesses appear to be the most important factors.

Present Practices

The following precepts are now being followed in Detroit:

1. Class 150 cast-iron pipe is unacceptable, and those sections now having an excessive breakage rate must be replaced.
2. Class 250 cement-lined cast-iron pipe is acceptable, and it is the only cast-iron pipe that will be used.
3. Use of Class 200 asbestos-cement pipe will gradually be increased, and it will be allowed to prove its worth, in 6- and 8-in. sizes, and under special installation practices.
4. Class 150 asbestos-cement pipe is unacceptable.
5. Mains 24 in. in diameter in either standard cylinder pipe or prestressed embedded-cylinder pipe and mains 16 in. and 20 in. in diameter in prestressed cylinder pipe will be accepted. Specifications on each job will spell out the construction standards, however.

Conclusion

Improved laying practices of all pipe have been adopted. More flexibility in the joints and better embedding practices have been adopted, and closer inspection in the field is necessary. The specifications applied to the existent construction and improved maintenance practices will, it is hoped, keep the system under reasonable trouble control and improve reliability.

Indianapolis—*Howard W. Niemeyer*

A paper presented by Howard W. Niemeyer, Supt. of Distribution, Indianapolis Water Co., Indianapolis, Ind.

The record of pipeline failures in the Indianapolis distribution system during the period 1926–54 was reviewed in the May 1955 issue of the JOURNAL in a discussion of an article by Leo V. Garrity.[1] In his article Garrity concluded that breaks in cast-iron pipe in Detroit were caused primarily by a combination of temperature stresses imposed by the restraint of sulfur compound joints and a progressive loss of pipe strength from corrosion. Although Indianapolis at that time was experiencing only three pipe breaks per year per 100 mi of main, compared to 20 in Detroit, analysis of those failures did lend support to Garrity's conclusion. The experience with pipeline failures since 1954 has provided additional supporting information, and it now appears that more than half of all the failures

that have occurred in pipe and joints in the Indianapolis system over the past 10 years can be directly associated with the use of sulfur compound as a jointing material. Experience has also indicated that centrifugally cast pipe in 18-ft lengths has not performed as well as pit-cast pipe in 12 ft lengths, both being laid with sulfur compound joints.

Indianapolis System

To evaluate the Indianapolis experience properly, the physical characteristics and certain environmental conditions of the system need to be known. The water supply for the city comes from a surface source, except that well fields formerly used have been maintained for emergency purpose. Water

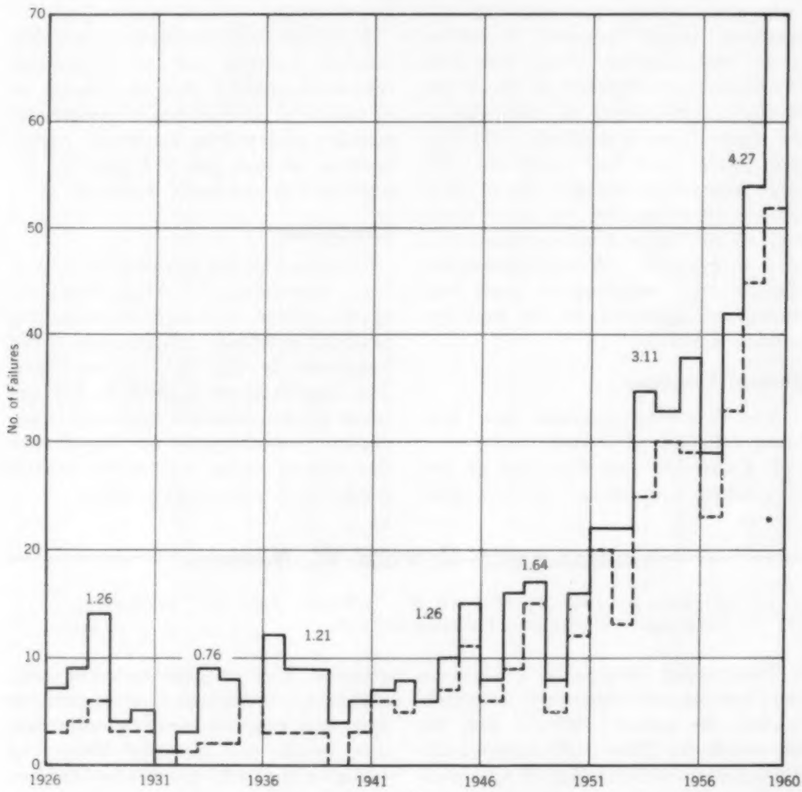


Fig. 2. Cast-Iron Main Failures Other Than Those Caused by Accidents or Freezing, 1926–59

The dashed curve represents that portion of the failures that was caused by circumferential breaks. Figures accompanying the curves represent averages per 100 mi of main per year.

temperature, therefore, has a seasonal variation which amounts to as much as 50°F between winter and summer. During prolonged cold waves, water temperature approaches 32°F. Ground frost penetration has varied over the years from a slight crust to as much as the 54-in. depth that was reached in the severe 1935–36 winter, the maximum penetration on record. The soil is for the most part clay, and, in general, there has been little evidence of corrosive action on the exterior of pipes, except in some isolated cases. It has rarely been necessary to install mains over filled ground. Cast-iron pipe has been used throughout the system, except for some bridge crossings and recently installed large feeder mains. The schedule of material types used is shown in Table 3.

TABLE 3

Types and Lengths of Indianapolis Water Mains, 1924–60

When Installed	Type	Class	Section Length *ft*	Jointing Material	Installed Length *mi*
Before 1924	pit cast	B*	12	lead	482
1924–38	pit cast	B*	12	sulfur	187
1938–50	centrifugally cast; unlined	150	18	sulfur	191
1950–60	centrifugally cast; lined	150	18	rubber	352

* Class C or D used in large transmission mains.

Mains were installed with 48-in. cover prior to the 1936 frost and 54 in. ever since. Installations have always been made in conformance with the best construction practices known with respect to pipe inspection and handling, trench conditions, and clearances with other structures. Service connections have been installed in a manner to avoid stresses from this source. Average distribution pressure is maintained near 55 psi with some maximums of 120 psi occurring in limited areas adjacent to one high-level pumping station and some of the boosters. The system has been successfully operated to avoid water hammer.

Pipeline Failures

In spite of the care used in constructing and operating the system, miscellaneous failures have occurred as a result of some occasional material and construction faults and because of conditions that have developed beyond control of the distribution engineers. Over the years the number of such failures has not been considered excessive; they were, therefore, accepted as normal operating problems. An increasing incidence of failure since 1940, however, has indicated presence of some factor or factors that apparently did not exist previously. The reason for any one failure is seldom obvious, and as it has been neither economically feasible nor practical to investigate each job for all factors present, no record of failures by cause has been accumulated for study. Much can be learned, however, by examination of job records as to the kind of failures that have occurred and the types of materials involved.

The quantitative record of pipeline failures during the period 1925–59 is summarized graphically in Fig. 2, showing pipe breaks, and Fig. 3, showing joint failures. These records exclude accidental damage to the system by adjacent construction and show

only those failures from normal causes. The exclusion is not intended to underrate the problem of damage failures which create emergency situations, disrupt normal operating patterns, and create added work loads for maintenance personnel. In the Indianapolis system, where damage has probably been no more extensive than in other systems, construction activity, largely for sewer construction, has been responsible for 223 pipe breaks and sixteen joint failures in the past 10 years. Also omitted from the records in Fig. 2 and 3 are nineteen emergency situations created by pipe breakage in hydrant leads from automobile collisions. The use of the breakoff hydrant in place of the solid-barrel type has been one solution to this problem.

The reader's attention is directed to the relatively small number of pipe breaks prior to 1941 (Fig. 2). In this early period of the record the incidence of pipe failures averaged only little more than one break per year per 100 mi of main—certainly a favorable record. There were no circumferential breaks in the years 1931 and 1939. The absence of any effect of severe winter temperatures on the incidence of breaks is to be particularly noted for the years 1936 and 1940. Since 1940, however, the incidence of pipe failures has steadily increased to a high of six failures per 100 mi of

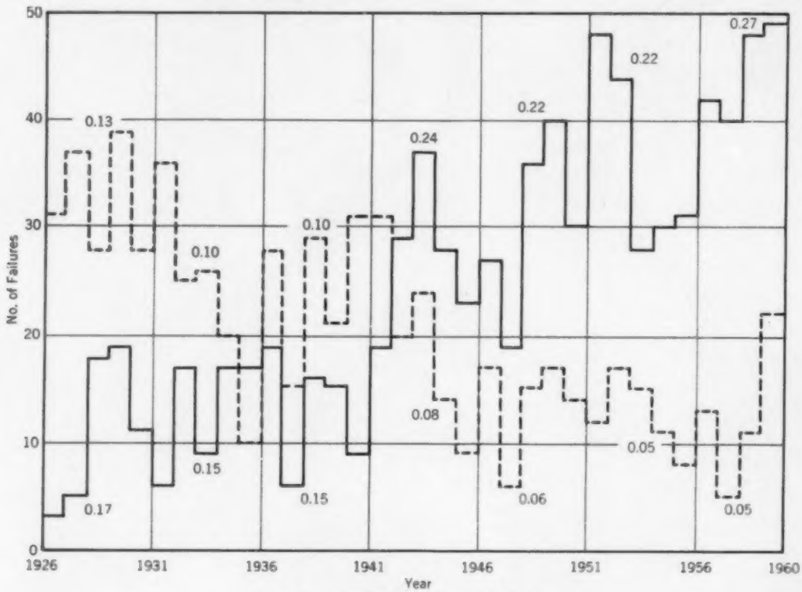


Fig. 3. Joint Failures, 1926–59

The solid and dashed curves represent failures of sulfur compound and lead joints, respectively. Figures accompanying the curves represent averages per 1,000 joints per year.

main in 1959, or six times the average prior to 1941. This increase has been almost entirely due to circumferential breaks which have accounted for 78 per cent of all breaks in the last 10 years. Other kinds of pipe failures have held a rather consistent relationship with miles of mains, amounting to an average of only about one per year for each 200 mi. An increase in the latter types of failures did occur in 1959 because there were nine instances of hole development in pipe from corrosion. The corrosion was later found to be the result of electrolysis in the vicinity of rectifier stations installed by the telephone company for cathodic protection of their underground cables, which paralleled the water main.

Jointing Materials

Figure 3 shows the performance of jointing material, for joint failures share equally with pipe breaks in the maintenance problems of distribution systems. It can also be shown that sulfur compound failures can be related to the temperature stresses imposed on pipelines by their restraint. No rubber gasket joint failures are recorded, as the trouble experienced with this type of joint has been very limited and has invariably resulted from improper tightening of the bolts in mechanical joints at time of installation. There has been no instance of mechanical-joint failure from corrosion of the bolts, although some of the bolts uncovered have shown evidence of galvanic action. Also excluded from the record are instances of rubber gasket joint failures on hydrants, bends, and other fittings if thrust blocking has shifted, permitting a joint to slip. There is a need for some simple and effective means to provide positive joint restraint where thrust blocking is required. The use of kicker blocks behind fittings is a crude and sometimes awkward method of countering thrust. Indianapolis is currently using stud type follower rings in addition to blocking on the mechanical joints of fittings as added assurance against thrust failures.

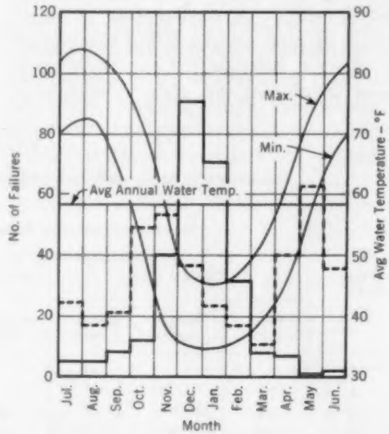


Fig. 4. Pipeline Failures by Month of Repair, 1950–59

The solid and dashed curves represent circumferential pipe breaks and failures in sulfur compound joints, respectively. As can be seen, circumferential breaks appear to occur during periods of low temperature, whereas joint failures occur during periods of rapid temperature change.

Joint failures have outnumbered pipe breaks in Indianapolis two to one in the past 10 years. Sulfur compound has been responsible for 75 per cent of joint failures, although only 35 per cent of all joints are of this material. It is interesting to observe from Fig. 3 that lead joints, which have the greatest age, are showing a decreasing

incidence of failure, whereas sulfur compound failures have been increasing. The seasonal pattern of both sulfur compound failures and circumferential breaks indicates a relationship of failure to water temperature. By plotting such failures by month of repair and superimposing water temperature curves on the graph as shown in Fig. 4, one can see a rather fixed relationship. A similar plot of other types of pipe breaks failed to produce a similar relation. Lead joint failures so plotted did show a somewhat frequency curve would probably be much more pronounced if the months of failure were known and used for this record rather than months of repair. Nevertheless, the relationship of failures to temperature is sufficiently clear to establish that the longitudinal stresses in pipelines imposed by restraint of sulfur compound are a cause of its poor performance. It is felt that material fails under fatigue of repeated stressing.

Again, in Fig. 4 the circumferential breaks are shown to start occurring

TABLE 4

Indianapolis Main and Joint Failures by Size and Material, 1950–59 *

Size *in.*	No. of Circumferential Breaks					No. of Joint Failures		
	Pit-Cast Pipe			Centrifugally Cast Pipe		Lead	Sulfur	
	Lead Joint	Sulfur Joint	Screwed Joint	Sulfur Joint	Rubber Joint	Pit-Cast Pipe	Pit-Cast Pipe	Centrifugally Cast Pipe
$2\frac{1}{4}$			20					
4	11					24		
6	31	8		148	17	25	43	28
8	10	5		18	1	9	37	10
10						7	1	
12	2			3		16	94	24
16	3					15	71	15
20	3					9	52	6
24–36	1					23	9	
All sizes	62	13	20	169	18	128	307	83

* Comparison should be made with Table 5.

higher incidence when water temperature was approaching its minimum, although not in a pronounced pattern.

From Fig. 4, it can be seen that sulfur compound failures have two peak periods of occurrence, in spring and fall when the water temperature is approximately at the annual mean. Minimum frequency is first at the maximum water temperature and then again after the minimum level has been passed. The peaks and valleys of the when water temperature falls to 40°F and to reach peak frequency when it is at 34°F or less. On several occasions when relief from high frequency has been desired, breaks have been stopped completely by the addition of well water to the surface supply, thus raising the water temperature by 4° or 5°F. This stoppage has been achieved regardless of the depth of frost penetration. It must, therefore, be concluded that longitudinal stress created

by temperature change has been a primary cause of circumferential pipe breaks during the past 10 years. As there is no evidence of cold-weather effects on the incidence of pipe breaks prior to 1941, it is necessary to analyze the records further to find factors that were not present at that time.

Comparison of Materials

From a classification of circumferential breaks and joint failures by sizes and types of materials (Tables 4 and 5), a difference in performance of materials in pipelines can be noted. It is significant that 85 per cent of the breaks has been in the 6- and 8-in. sizes and that 70 per cent of these has the same percentage of total mains as the centrifugally cast pipe. The difference in the performance of the two types of pipe with the same jointing material must be attributed either to the difference in wall thickness or to the longer joint spacing of the centrifugally cast pipe, or to both. In comparing the performance of the sulfur compound installed in these two types of pipe material, it is found that 32 per cent of its failures in 6- and 8-in. sizes occurred in the centrifugally cast pipe and 68 per cent occurred in the pit-cast pipe, even though the shorter length of the latter reduces the longitudinal stress to be absorbed by each joint by one-third.

TABLE 5

Pipe and Joint Failures by Material, 1950–59

Type of Pipe	Type of Joint	Avg. Length of Mains in Service *mi*	No. of Breaks per 100 mi.	Avg. No. of Joints in Service *1,000's*	No. of Failures per 1,000 Joints
Pit cast	lead	482	12.9	241	0.53
	sulfur	187	7.0	94	3.27
	screwed	5	400.0		
Centrifugally cast	sulfur	191	88.5	74	1.12
	rubber	159	11.3		

occurred in the unlined centrifugally cast pipe laid with sulfur compound joints, although the combination of materials represents less than 19 per cent of the total mains in the system. There was a high incidence of sulfur compound failures in the larger sizes of pipe of this construction, although there was a complete absence of pipe breaks. It is also significant that only 5.5 per cent of the breaks have been in the pit-cast pipe laid with sulfur compound joints, even though the pipelines made of this combination of materials have been in service an average of 13 years more and represent about

Beam Action

It is recognized that beam action or cantilever action stresses of varying degree have attended many of the circumferential breaks and have contributed to their incidence. On the other hand, in a great many of these breaks the ruptured ends of the pipe have opened up as much as ¼-in. with the ends remaining in perfect alignment, indicating absence of deflection and the presence of contraction only. Aside from the influence of beam action, the record does indicate that the centrifugally cast pipe laid with sulfur compound joints has not satisfactorily

withstood the longitudinal stress from temperature change and has contributed heavily to the Indianapolis record of failures. The rising incidence of failures would indicate either a progressive loss of pipe strength from corrosion or failures from metal fatigue. The pit-cast pipe appears to have failed from beam or cantilever action, and its joints have failed from longitudinal stress.

Age of Pipe

With regard to failures in the pit-cast pipe laid with lead joints, it should be pointed out that these mains range in age from 35 to 80 years. This early pipe was not manufactured with the quality control that has been used in more recent years. It has been subject to tuberculation and whatever external corrosive conditions have existed, especially some known electrolysis in the days of streetcars. This pipe is all contained in the central and oldest part of the city where many of the streets are crowded with every possible type of utility structure. Many of the other utility lines lay over or under the water mains and they have not always been installed with proper clearances. Under such conditions, an incidence of slightly more than one circumferential break per year in each 100 mi of old mains is not surprising.

Other Factors

The use of the rubber gasket joint has eliminated horizontal stressing from temperature variations, and will help to avoid failures. The use of cement lining will eliminate the loss of pipe strength by internal corrosion. These improvements, however, will not prevent failures caused by other factors. The incidence of circumferential breaks in centrifugally cast pipe with rubber gasket joints has been shown (Fig. 3) to be much lower than in the same pipe with sulfur compound joints, but not so low as in pit-cast pipe with sulfur compound joints. It must be recognized that an 18-ft length of 6- or 8-in. pipe is a reatively poor beam and will fail under abnormal beam action stresses. It must also be recognized that such abnormal stresses will naturally develop from changing conditions in a system and are beyond control of the utility. A trouble-free system can, therefore, be attained only by providing allowances for such stresses. Heavier wall thickness, shorter lengths, or a more ductile iron, at least for the smaller diameter pipe, may provide a desirable improvement. Ductile iron appears to be more desirable, as it not only provides the needed elasticity and deflection limits, but also resists impact damage in pipe handling and from accidents.

Economic Considerations

Economic considerations have obviously had much bearing on the design of pipelines for distribution systems. Installation savings, however, are only temporary economies, if they result in a high incidence of failures. The property damage that frequently results, the unscheduled disruptions to customer and fire protection services, the cost of repairs, and the hardship imposed on maintenance personnel who must frequently work long hours under most adverse weather conditions are adverse consequences of water main failures. The distribution engineers must decide if the failure experiences in any one system justify the cost of improved materials.

Circulation of Water in the Hammond Distribution System

Thurston E. Larson, John C. Guillou, and Laurel M. Henley

A paper presented on Mar. 17, 1960, at the Illinois Section Meeting, Chicago, Ill., by Thurston E. Larson, Head, Chemistry Sec., Illinois State Water Survey Div., Urbana, Ill.; John C. Guillou, Assoc. Prof. of Hydraulic Eng., Univ. of Illinois, Urbana, Ill.; and Laurel M. Henley, Chemist, Illinois State Water Survey Div., Urbana, Ill.

THE aim of every water utility is to produce the best possible quality of water for the consumer. Treatment practices commonly employed can produce any quality of water that may be desired. The treatment, however, must be consistent with distribution practice, in order to avoid deterioration of the distribution facilities and of the water quality. A perfectly clear, soft, and safe water entering the distribution system may be unrecognizable as such at the household tap, if the quality produced is incompatible with the design and operation of the distribution system. Treatment and distribution operations are intimately associated and, of necessity, demand joint and coordinated attention even at the design stage.

Distribution Problems

The many problems of distribution pertaining to water quality include the problem of slime growths, which may develop from the accumulation of bacteria thriving on iron, methane, ammonia, sulfide, sulfates, or organic matter. These growths usually represent the development of a single organism, but may often consist of a zoogloeal mass of a number of organisms. The growths may be so luxurious that normal chlorination practice cannot cope with the rate of growth. On death and decay of these organisms, taste and odor problems often develop. Slime growth on pipe walls can also cause serious loss in carrying capacity. On surges in velocity, the growth may slough off and appear as particulate matter at the consumer's tap.

A similar loss in carrying capacity may result from the passage of aluminum hydroxide due to improper filtration, or after-precipitation may result from unsatisfactory coagulation and retention periods. At lime-softening plants, lack of attention to the removal of excess magnesium hydroxide can cause similar results. Another problem is corrosion of exposed steel and cast-iron components of the distribution system which may result in red water at the household tap. In household use, such water causes many difficulties.

These types of problems are not limited to geographic areas or to sizes of individual distribution systems. In many instances, controlled chemical treatment can overcome these problems and reduce the number of consumer complaints. In chronic problem areas,

where complaints are not entirely eliminated, chemical treatment must be supplemented by mechanical means.

It has long been recognized that the greatest number of problems develop in the dead ends of the distribution system and that the elimination of dead ends often solves the problem by providing more frequent turnover or shorter retention times. If connecting the dead ends does not eliminate the problems it may be deduced that the dead ends had been converted to "dead loops," with no circulation of water. This situation often exists in small communities where water is supplied to one end of a carefully looped system. In such an instance, the system is composed of pipe with a diameter sufficient to yield 500-gpm fire flows at the most remote point. Actually, the normal water demand may be only 500 gpd, a ratio of 1,440 to 1 between fire flow and normal demand. Obviously, the velocity of flow for normal use is extremely low, or, in other words, the time of contact of the water with the pipe surface is very long.

When water in pipe is exposed for long periods to holidays in the pipe coatings and to joints along the path to the dead loop, one or several effects may occur, which, singly or in combination, contribute to cumulative deterioration of water quality: Chlorine treatment for sanitation can be destroyed by biologic growths before the chlorine reaches the ends of the system. Similarly, dissolved oxygen may also be exhausted biologically, and, as a result, anaerobic conditions may develop at the ends of the system. New species of organisms that thrive in the decaying process of dead organisms then develop at the ends of the system. Such organisms produce methane and acidity in the form of carbon dioxide, as well as foul odors. The ends of the system then serve as a septic tank for dead organisms. Also, corrosion can take place, with or without the aid of organisms or oxygen, and at a rate that exceeds the rate at which protective minerals can reach the point of attack for effective protective action.

It must be recognized that minerals or additives that protect against corrosion must act at the point of corrosion in order to be effective. Diffusion of minerals in stagnant water is extremely slow. Low-rate laminar flow conditions are no better. Improvement of protection may be expected by increasing turbulent flow rates.

Hammond System

The foregoing problems developed at Hammond, Ill., a community of 400 people. Hammond has an adequate water supply in quantity. It also has treatment facilities to provide aeration for the removal of hydrogen sulfide and methane, and facilities for oxidation of iron (9–12 ppm), chlorination prior to filtration, and softening by ion exchange to reduce the hardness from 375 to 95 ppm.

This system, which was installed in 1935, produced a plant effluent excellent in taste, odor, color, hardness, and sanitary quality. For 24 years, however, red water had occurred at the end loops of the system. The iron content of the raw water had been determined at various times to be 5–9 ppm with a plant effluent of 0.01–0.5 ppm. Distribution system samples had shown iron concentrations as large as 4.6 ppm and 7.5 ppm in 1955 and 1956.

During the 24-year period, flushing had been practiced liberally—to the extent that the 50,000-gal storage tank

would permit—with the result that only temporary relief was achieved for the segment of the system that could be flushed at one time. Treatment for pH adjustment with soda ash had been practiced early, but abandoned because of its ineffectiveness. In recent years, polyphosphate had provided partial relief by keeping the iron in solution, usually eliminating the rusty appearance at the tap. The water still had detrimental effects on laundered clothes and dishwashers, and taste and odor problems at the far ends of the system were not abated. Chlorination was never effective beyond a quarter mile from the plant, except at times of flushing. The community needed industry that would consume a large quantity of water at the distant end of the distribution system.

With no treatment alternative in sight, it was decided that induced velocity, if economically feasible, would be a decided aid to treatment. Different phases of the problem were studied. Analyses were made of the existing flow pattern, to provide time of travel to various points in the existing system, and of data on relative velocities of flow. It was determined whether it was feasible to recirculate water through the plant for reclarification and thus provide periodic circulation in the dead loops with velocities of 1 fps or 2 fps. Studies were made of an alternate system design in order to obtain minimum time of contact in the mains and still satisfy the minimum fire flow requirements.

System Analysis

The water supply system at Hammond is composed, almost exclusively, of cast-iron pipe, with a peripheral loop 6 in. in diameter and internal distributors 4 in. in diameter. The topography is flat, and all mains are virtually level. The average pumpage in 1957 was 11,220 gpd, or slightly less than 30 gpcd. The water supply, obtained from two wells in the Illinoian drift, is pumped, after treatment, to a 50,000-gal elevated tank. Both the treatment plant and the elevated tank are located at the mercantile end of the distribution system. Flow data available for analysis consisted of monthly consumption values for each connected household. These values were consolidated at quarter-length load points on each distributor.

Analysis of the flow distribution in the system was completed with the use of the Darcy equation and the Moody diagram, rather than with the usual Hazen and Williams equation. This procedure was necessary to obtain reasonable flow times because of laminar flow in the pipe. After completion of the flow distribution study, the velocity of flow in each pipe was determined; then the time of flow to various points in the system was calculated. At selected points in the system, the mean time required for the flow to reach the point from the elevated tank was computed from the inflow rates and times. The results of the initial calculation are shown in Fig. 1.

The mean flow time from the elevated tank to any junction is indicated by a boxed value in Fig. 1. The longest flow time in the system was 163 hr, or nearly 7 days. The maximum velocity of flow in the system was 0.045 fps in the 6-in. pipe just north of the 8-in. main from the pumping plant.

A comparison of the calculated flow times with the record of complaints about red water indicated that a time

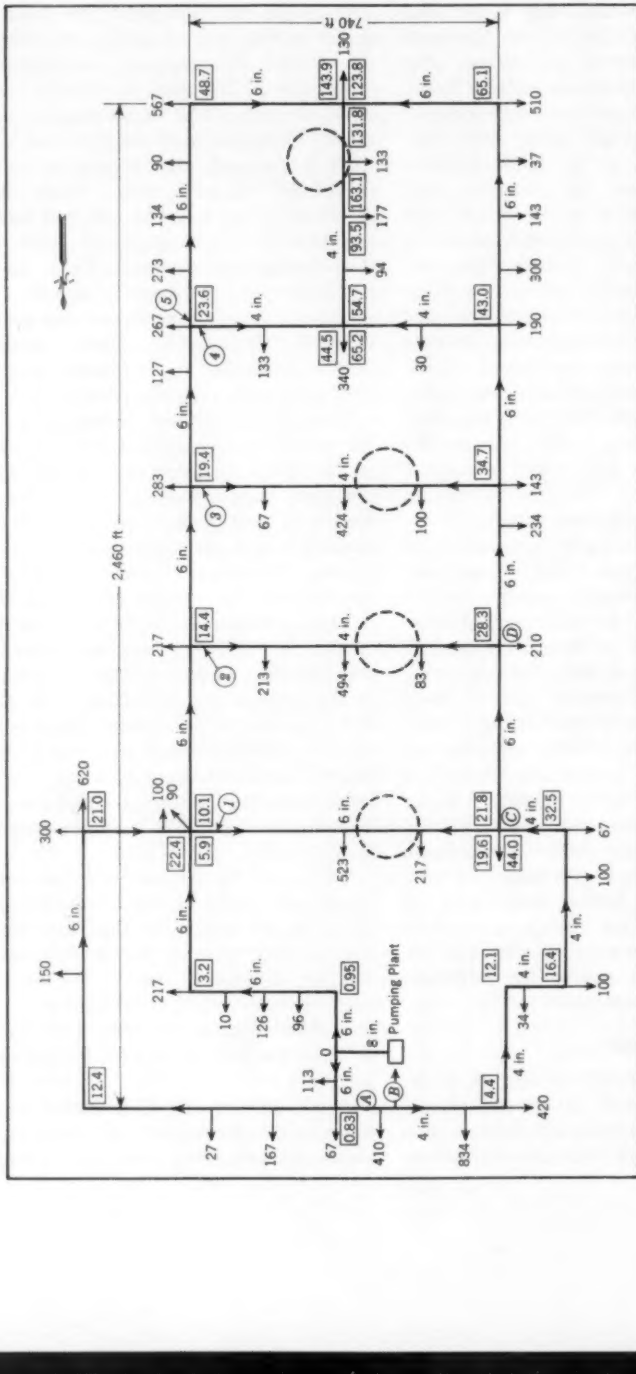


Fig. 1. Analysis of Distribution System at Hammond: Existing Flow Conditions, June 1957

The values for mean flow times, in hours, from the elevated tank to the pipe junctions are boxed. The other values represent concentrated takeoffs in gallons per day. The circled portions of the diagram indicate the four areas of stagnation in the original system. Points A and B are pertinent valve locations. Points C and D relate to reductions in the ratio of flow times. Circled numbers locate valves noted in Fig. 4.

of travel longer than approximately 40 hr was sufficient to cause objectionable deterioration of water quality. The fact that the average daily demand of 11,200 gal was equal to only four-fifths the volume of the distribution pipe clearly indicates the difficulty of maintaining satisfactory water quality by flushing, unless the initial supply is exceedingly stable.

the purposes of the recirculation study, all of the flow from the plant was caused to pass through the east side of the loop and into the system by the closing of an existing valve in the 4-in. main north of the elevated tank. This closure established a clockwise flow in the loop system, and the interior distributors acted as short circuits to the loop flow.

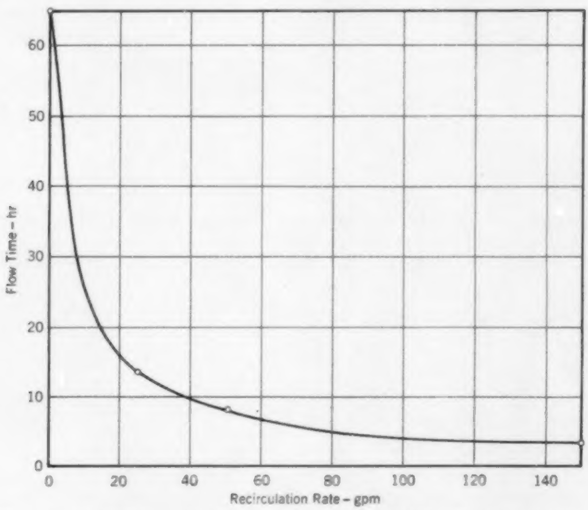


Fig. 2. Flow Times to Southwest Corner of Distribution System

The recirculaton curve permits the determination of the required time of travel to the southeast corner of the distribution system for any rate of recirculation.

Recirculation Analysis

The feasibility of improving the water quality by recirculation was dependent on the creation of a continuous pattern of flow through the system and on the reduction of the time of flow to any point in the system to approximately 40 hr or less. The four areas of stagnation in the original system (Fig. 1) were caused by allowing flow to move from the plant through both sides of the 6-in. peripheral loop. For

The purpose of the second phase of the study was to determine the rate at which water should be taken from the system to establish desirable velocities in all the mains. Again by applying the Hardy Cross method of network analysis and the Darcy equation, with variable resistance coefficients, the times of flow to junctions in the system were determined. The pattern resulting from the rate analyses made periodically during 1958 showed that a 50-gpm

recirculation rate and a closed valve on the 4-in. main north of the pumping plant would cause the elimination of the four stagnant areas shown in Fig. 1. Moreover, the recirculation rate caused the time of travel to the southwest corner of the system to decrease from 65 hr to 8 hr.

Similar calculations were completed for recirculation rates of 25 and 150 gpm. For each rate, the time of flow to the southwest corner of the distribution system was obtained. These time values, plotted against rate of recirculation, are shown in Fig. 2. The purpose of the figure is to permit the determination of the required time of recirculation for any rate of recirculation. For example, treated water would be caused to reach the southwest corner of the system by recirculation at the rate of 50 gpm for 8 hr, or 150 gpm for 3.5 hr. The time values denote the average flow through the system, not the time required to change all the water in the system.

The significance of flow rate in reducing travel time to the southwest corner of the system is further shown in Table 1. It is noted that the low recirculation rate was responsible for most of the reduction in travel time. For example, increasing the rate from 25 to 50 gpm caused a 23 per cent reduction in travel time; four times this rate of change, from 50 to 150 gpm, caused only a 7 per cent reduction. It is apparent that the lower rate of induced flow is desirable from the standpoint of operation, because the recirculation equipment is used for a longer period of time each day, and thus the capital cost is reduced.

Not only the equipment cost but also the operation cost is less for low recirculation rates. As shown in Table 1, it is necessary to circulate more water at high rates than at low rates, in spite of the reduced time of operation. Under the conditions at Hammond, the minimum annual power cost for a 25-gpm circulation is estimated to be approximately $75. This figure is based on the condition that the flow will be passed through the aerator and the filter and be returned to the elevated tank, approximately 100 ft above ground. If, instead of being passed through the aerator, the recirculated water were treated under pressure and returned to the supply main, the minimum power cost would be less than $10 per year.

TABLE 1

Recirculation Data—Southwest Corner of System

Recirculation Rate *gpm*	Max. System Velocity *fps*	Travel Time *hr*	Reduction in Travel Time		Volume Recirculated *gal*
			hr	%	
0	0.045	65.1			
25	0.216	13.6	41.5	64	20,400
50	1.31	8.2	56.9	87	24,600
150	3.82	3.5	61.4	94	31,500

The existence of a 6-in. crosstie in the peripheral loop required a refinement in the recirculation program. At 50-gpm recirculation, a large amount of recirculated water passed through the 6-in. line south of the pumping plant. This was evidenced by the fact that the travel time for water reaching the east end of the line from the west portion of the peripheral loop was 1.6 hr, while water from the south required 7.5 hr to reach the same point. The average transit time for water leaving this point was 3.9 hr. To remedy this problem, a valve in the

6-in. crosstie of the 5th St. main south of the pumping plant was closed, causing all of the water to reach at least the first 4-in. distributor before crossing to the east side of the peripheral loop. A new time pattern was established by this action.

The recirculation pattern was materially aided by the elimination of the crosstie. The ratio of flow times at the west end of the northerly distributors (at Points *C* and *D*, Fig. 1) was reduced from 4.7 (*C*) to 2.2 (*D*) with the 5th St. main open and closed, respectively. The increased flow through the southerly distributors also reduced the time of travel, and thus improved the water quality, at other points in the system. For example, at the southwest corner of the system the travel time was reduced from 8.2 hr to 3.9 hr.

It is recognized that the closure of the 5th St. valve affects adversely the adequacy of two fire hydrants at the north end of the west side of the peripheral loop. Calculations indicate that this problem is not serious. Closure of the valve reduces the crossflow pipe area by approximately 30 per cent and increases the average crossover velocity for a 750-gpm demand from 2.2 fps to 3.1 fps.

Alternate System Design

The existing distribution system was designed to satisfy the fire flow requirements by gravity flow. Analysis showed that the gravity capability of the system at the far end is approximately 720 gpm. Insofar as rate of flow is concerned, this is substantially in excess of liberal fire flow requirements. In fact, in order to obtain turbulent flow rates in any dead loop of 6-in. pipe, a nominal velocity of 0.2–0.3 fps must be attained, or approximately 15–20 gpm for a 16-hr day. This would require a population of at least 150–200 persons or 43–50 family dwellings on two or three sides of a city block. At best, such conditions would be called crowded living. For 4-in. pipe, the number of users and dwellings could be reduced by one-third.

In an effort to reduce the volume of water contained in the distribution system, and thereby reduce the time available for deterioration of water quality, the system was redesigned. The new system used smaller pipe sizes and substituted a central main for the peripheral loop. The system was conceived as a compromise between current fire protection recommendations and the requirement of supplying a good quality water for normal consumption. In the compromise system, liberal fire flow can be attained only with the use of fire pumps. The system is shown in Fig. 3; characteristics of the original system and the redesigned system are shown in Table 2.

TABLE 2

Characteristics of Original and Redesigned Systems

System	Pipe Surface Area *sq ft*	Water Volume *cu ft*	Ratio of Volume to Demand	Total Cost *$*
Original	16,334	1,858	1.25	78,690
Redesigned	13,866	1,358	0.91	74,537
Reductions—%	15.1	26.9	19.2	5.3

The volume of the redesigned system is approximately nine-tenths of the daily demand; the volume of the existing system is 25 per cent greater than the daily demand. The travel time to the southwest corner of the redesigned

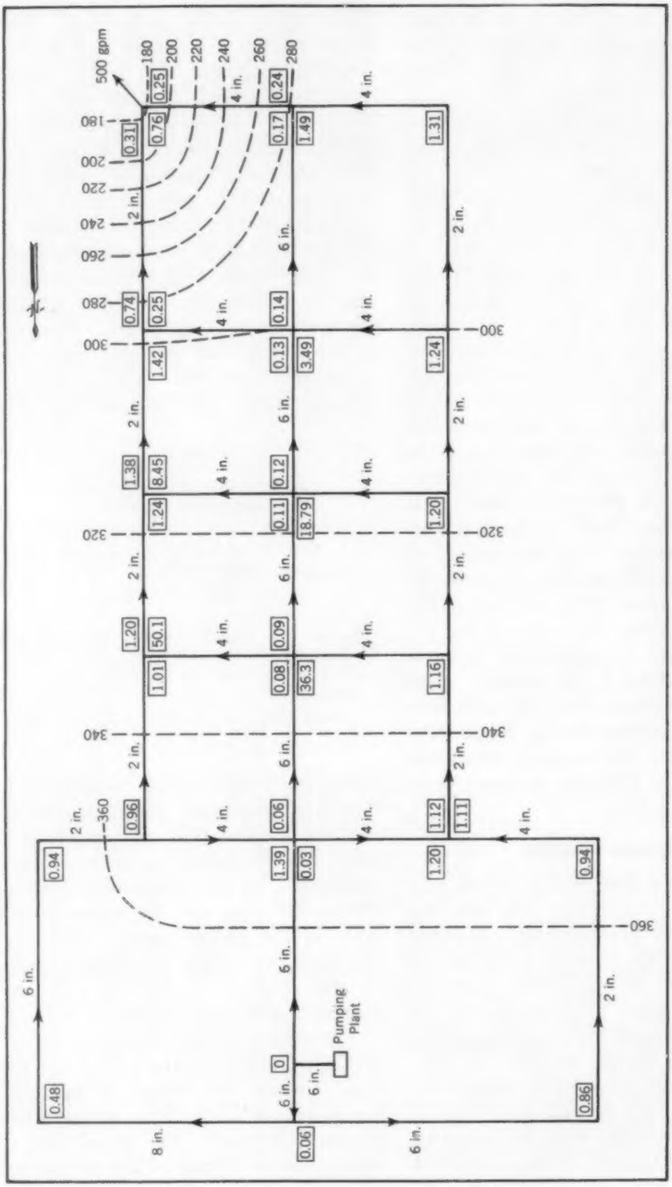


Fig. 3. Fire Flow Analysis of Redesigned System

The boxed values are flow times in hours. A number at the end of a dashed curve or line represents head, in feet. The head at the pumping plant was 380 ft.

system was estimated to be approximately 14 hr, as compared to 65 hr for the existing system.

Cost figures shown in Table 2 include the cost of Class 200 pipe for the redesigned system and Class 100 pipe for the original system. Prices for material and excavation were based on 1947 data and adjusted upward with the use of the *Engineering News-Record* cost index.

The rate of gravity fire flow that can be delivered at the far end of the redesigned system is 207 gpm, materially less than the 720-gpm capability of the original system. But with the use of a small fire pump in conjunction with the elevated tank, the delivery rate of the redesigned system could be made to exceed single fire stream requirements in all parts of the residential areas.

The time and head loss patterns that would develop if a 500-gpm flow requirement were to be satisfied at the southeast corner of the system are shown in Fig. 3. Such a demand would require a head of 380 ft at the pumping plant during the time of fire flow delivery. This induced head during fire flow would require the protection of household plumbing by pressure regulators on the service lines.

Another factor that should be considered in the design of the system is the location and use of the elevated tank. In Hammond, virtually all of the treated water storage is elevated. Water is pumped from the wells, treated, and delivered to the elevated tank for approximately 3–4 hr each day. During the rest of the day, water is supplied to the system directly from the tank. The total volume of water in the tank and in the distribution system is 63,900 gal. Thus, the normal daily demand is less than one-fifth of the total storage. Because practically all of the domestic supply must pass through the elevated tank before entering the system, the average retention time, in tank and system, is longer than 5 days.

This very low turnover time could be greatly improved if the elevated tank and the treatment plant were located at opposite ends of the system. Such a procedure would result in the pumping of treated water through the mains to the elevated tank. Consequently, more of the system would have its water replaced at least every day. Such an arrangement would also provide a better fire flow capacity, because water would reach the hydrant from both ends of the system.

Operations

Because of these facts, Hammond installed a 1.5-in. line with a T connection to permit circulation through the aerator or directly to the iron removal filter or elevated tank. The plan and objective were explained to the homeowners, and those who had not experienced the severe conditions were warned to expect temporary red-water problems. As this was a 24-year-old problem, there were no objectors.

On Aug. 4, 1959, the valve at *A* in Fig. 1 was closed and the valve at *B* opened to permit the water to return to the top of the aerator at a rate of 65 gpm. The existing pump delivered the water to the filter and back to the elevated tank. This cycling of water was maintained for 10–20 hr daily during the period when the normal replenishment of treated water was not carried out.

During the first period, most of the circulation took place in the 6-in. cross main, within a block of the plant, but some was obtained at other mains, as

indicated by the range of iron concentration in the water returned to the aerator. Samples were collected at the beginning and end of circulation periods; during periodic visits, ten samples were collected from various hydrants after approximately 10 min of slow flow caused by "cracking" the hydrant valve. These samples were representative of the water in the distribution system at that point (Fig. 4).

After a week, the 6-in. main was valved off and the polyphosphate treatment stopped, because it prevented the removal of iron by filtration. A week later, the next cross main was also valved off. By this time, nothing but favorable comment was received by the plant operator, who warned consumers that more red water would develop for what was hoped would be a temporary period.

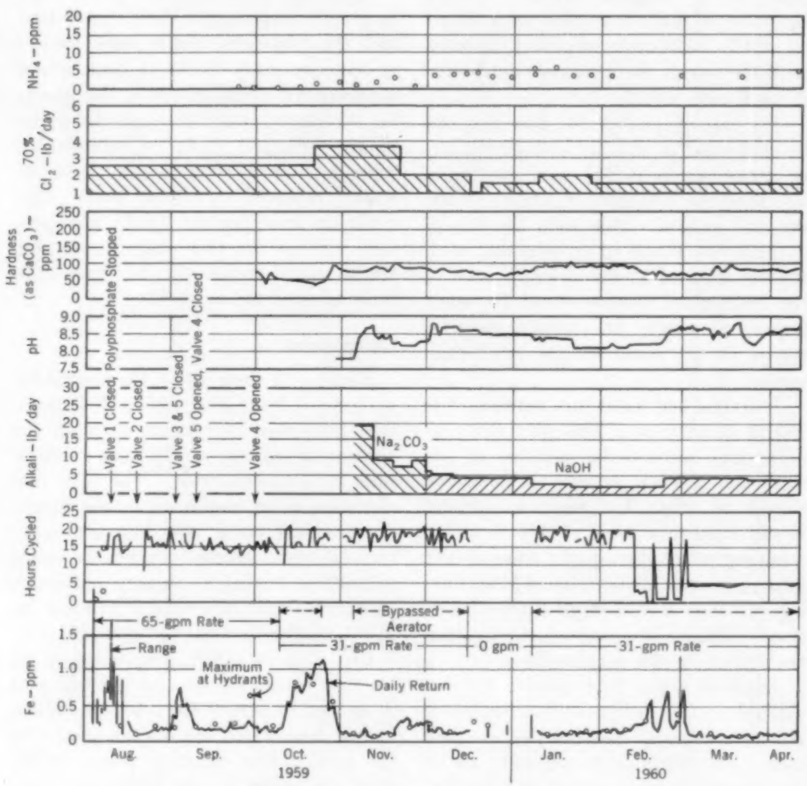


Fig. 4. Analysis of Water Samples

Shown is a summary of data collected during cleanup and development of treatment and circulation for the system.

The next valve was then closed, and a week later another was closed. With minor changes to accommodate expected localized flare-ups, this operation was continued for a month; an average iron concentration of 0.2 ppm was found in the return water. It was then decided to reduce pumping costs by bypassing the aerator. A new 30-gpm pump ($\frac{1}{3}$ hp) provided a velocity of 0.4 fps in the 6-in. main and 0.9 fps in the 4-in. mains.

Prior to this time, the circulated water was reaerated and rechlorinated, thus providing a plant effluent with an iron concentration of less than 0.1 ppm. Carbon dioxide was also removed on reaeration to provide a pH of 8.0. When the aerator was bypassed, the soluble iron was not removed by passage through the aerator, and in 2 weeks the return water had more than 1.0 ppm iron. Also, the pH of the water was approximately 7.7–7.8. Complaining consumers were patient but persistent. The aerator was put back into service, and in 2 days the iron concentration in the return water was 0.5 ppm; then a power failure drained the elevated tank during the night.

When the iron concentration of the returns was again less than 0.3 ppm, it was once more decided to bypass the aerator, but also to supplement the circulation by pH adjustment with soda ash applied to the filter effluent during recirculation. Caustic soda replaced the soda ash when depleted. After 6 weeks of successful operation, the circulation was stopped, with caustic soda applied to the treated plant effluent for a period of 3 weeks; then the borrowed feeder for caustic soda had to be returned.

The concentration of dissolved oxygen in the plant effluent was 6–7 ppm at first and 0 ppm within a quarter mile of the plant, prior to induced circulation. On return of circulation to the plant, the average concentration was 0.5 ppm. When pH adjustment was initiated, a similar oxygen concentration was obtained, even without circulation. The greatest oxygen demand in the system occurred during periods when iron was being picked up. There was no quantitative relationship between iron pickup and loss of dissolved oxygen.

During plant operation, chlorine is added in front of the iron removal filter to maintain oxidizing conditions and to prevent biologic growths in the iron removal filter and the softener. Although chlorination called for a chlorine dosage of approximately 6–7 ppm, with about 1 ppm in the effluent, chlorine residuals were not obtained throughout the system until circulation was provided and the chlorine applied to the circulated water as well as to the treated makeup water.

On Feb. 13, 1960, the new caustic feedpump was installed. Circulation was limited to 2 or 3 hr per day, and 25 ppm NaOH was added to the plant effluent. Four days later, circulation was stopped, but in 2 days the iron concentration had increased to 0.6 ppm. Circulation overnight remedied the situation, but 4 days later the iron concentration had again increased to 0.6 ppm. The sodium hydroxide treatment was increased to 50 ppm, and circulation overnight again cleared up the water, but 6 days later it once more became necessary to circulate the water.

A final schedule of operations was begun on March 11. Circulation for 6 hr per day was begun, and 20 ppm NaOH was applied to the treated effluent of the elevated tank; 8 ppm was

applied to the circulated water. Also, 2.7 ppm chlorine was applied to the treated water and 2.0 ppm to the circulated water. This treatment provided a water with less than 0.1 ppm iron and a chlorine residual at all points in the distribution system.

It is significant that the cost of pH adjustment is $12 per month, and the cost of circulation much less than $1 per month. Of interest is the fact that the average daily demand at this time is 18,000 gpd, whereas it was approximately 12,000 gpd in 1956 when the distribution system problem was first considered. It is recognized that the closed valves on the system affect the adequacy of fire protection, but this hazard is not as great as that normally encountered at other places, because the buildings at Hammond are low and widely spaced at the weakest points in the system.

Summary and Conclusions

Work at Hammond has shown that induced circulation can be effective in maintaining a quality product at the household tap and that the annual cost of the operation is negligible. The operation is applicable to troublesome areas of both large and small distribution systems. More imaginative engineering design is needed for water distribution systems in order to maintain a water quality that meets the USPHS Drinking Water Standard. It should be recognized that ineffective distribution, as well as improper treatment, can result in the deterioration of water quality. There is also a need for low-head, in-line velocity boosters that do not interfere with fire flows. Studies should be made of the design and use of pressure sensitive valves that can be used to direct the flow of circulated water and still permit satisfactory fire flows.

Acknowledgment

The authors thank the plant operator, George Silvers, for his sincere cooperation. The support of Mayor R. B. Ponder, the village board members—Robert Lowe and Harold Adams—and, particularly, a former board member, Paul Willey, was at all times enthusiastic.

Discussion

Abel H. Gent

Chief Engr., Illinois Inspection Bureau, Chicago, Ill.

It is, of course, evident that the closed valve is a recognized risk in fire protection. For manual fire operations, this risk can be modified somewhat by having a predetermined plan of cooperative action by the water department and fire department for developing the ultimate designed distribution system capacity for times of fire. This plan should include a definite recorded procedure for the immediate opening of valves during fire emergencies in the various neighborhoods affected.

The complete accessibility of these valves at all times must be insured, and it would appear that the practice of indicating the type of valves in vaults or manholes and the use of post-indicator valves at some locations where practicable may be justified. Regular cooperative drills in the use

of the predetermined plan would also appear necessary.

In a small community such as Hammond, Ill., this cooperative plan of action is not difficult to accomplish, so that even at extreme outlying sections not less than 500 gpm of water can be obtained for fire department pumper use at 20 psi residual pressure, in noncongested residential areas with low buildings of small area. The regular drills and the necessary procedures also fit into a routine operation, because periodically closed valves must be opened to provide flushing for the dead ends created by this means of operation. As regular use increases, owing to the improved water quality that is expected, it is apparent that fewer closed valves will be required to produce the desired result.

Of course, where automatic fire protection is required, dependence on the development of adequate distribution system capacity by manual means is not considered acceptable. Where limited use affects water quality, the design of completely reliable automatic circulating booster and pressure sensitive valve equipment, such as referred to by the authors, would be necessary to insure the development of the ultimate capacity needed for fire protection by automatic means.

Annual Report of Joint Committee on Uniformity of Methods of Water Examination

A report released in May 1960, by the Joint Committee on Uniformity of Methods of Water Examination, for publication by each of the member organizations.

THE Joint Committee on Uniformity of Methods of Water Examination (JCUMWE) has completed its fourth year of operation. As stated in previous annual reports,[1] the objectives of JCUMWE are to:

1. Review the methods of water examination, published by member organizations, for the purpose of obtaining uniformity in sampling, testing, reporting test data, terminology, and application
2. Provide a mechanism for the exchange of information on these matters by member organizations.

The objectives of JCUMWE are accomplished by review panels made up of experts in their fields of specialty. A review panel is established for each method undergoing review. Official JCUMWE recommendations have been approved for:

1. Reporting of results
2. Total hardness
3. Iron
4. Organic nitrogen
5. Grease and oily matter
6. Solids.

The last four were approved during 1959. The recommendations have been transmitted to member organizations.

An important precedent was established in the JCUMWE recommendations for grease and oily matter. After a thorough study by the panel and the member organizations, it was decided that it is impossible to reach uniformity for the several methods that were reviewed. The reasons are that the objectives of the several methods are different and that the different solvents used in the methods give results for which there is no basis for comparison. It is not unlikely that certain other methods that come under review by JCUMWE may result in similar conclusions.

Reports of three panels—sulfates; uniformity of reagents; and acidity, basicity, and alkalinity—were accepted as preliminary recommendations. These recommendations will be sent to member organizations for review and comment. The following new panels are to be set up as soon as practicable: turbidity; calcium and magnesium; carbonate, bicarbonate, and carbon dioxide; electrical conductivity; fluoride; ammonia; total phosphorus; and nitrite. Progress was made on certain proposed revisions of the regulations governing the activities of JCUMWE.

The status of the American Society of Mechanical Engineers changed from inactive to active in 1959, which brings the total to eleven of the twelve member organizations that are maintaining

active participation in all phases of the program. They are: American Petroleum Institute, American Public Health Association, American Society of Mechanical Engineers, American Society for Testing Materials, American Water Works Association, Association of Official Agricultural Chemists, Manufacturing Chemists Association, Technical Association of the Pulp and Paper Industry, United States Geological Survey, United States Public Health Service, and Water Pollution Control Federation. The United States Pharmacopoeial Convention still maintains membership for information purposes.

Reference

1. JCUMWE STATEMENT. Purpose and Policies of the Joint Committee on Uniformity of Methods of Water Examination. *Jour. AWWA*, 50:835 (Jun. 1958).

Preview of the Eleventh Edition of *Standard Methods*

Summarized below are some of the features of the forthcoming eleventh edition of "Standard Methods for the Examination of Water and Wastewater." Like the preceding tenth edition (which was titled "Standard Methods for The Examination of Water, Sewage, and Industrial Wastes"), the eleventh edition will be published jointly by American Public Health Association, American Water Works Association, and Water Pollution Control Federation, under the direction of a Joint Editorial Board on which all three organizations are represented. The price of the new edition is $10. AWWA members wishing to use discount coupons should order through the AWWA Order Department, 2 Park Ave., New York 16, N.Y. (Members may purchase $10 worth of coupons for $8 cash.) Others may order direct from American Public Health Association, 1790 Broadway, New York 19, N.Y., which will act as the distributor of the volume.

THE eleventh edition of *Standard Methods,* scheduled for publication in September 1960, will be a major expansion of the tenth edition. To conform to advances in analytical techniques and in processes of water and waste treatment, the new edition will include many changes in specific methods and the addition of new sections and new test procedures. The length of the volume has been increased 25 per cent. The general format will be unchanged and, as in previous edition, simple procedures for the control of treatment processes will be found, as well as more complex tests for special and research investigations. The material will be presented in nine numbered parts, three more than in the tenth edition.

In the Preface, a new policy is outlined whereby during the periods between editions, methods designated Tentative can be advanced to Standard, by action of the Joint Editorial Board and approval by the sponsoring associations. The acceptance of new procedures as Tentative or Standard will be recognized by publication in one or more of the journals of the three associations. No method can be deleted or reduced from Standard to Tentative before publication of a succeeding edition.

A General Introduction has been included, incorporating some of the information previously appearing in the introductions to the separate parts. The discussion of the statistical treatment of data, included in the General Introduction, has been expanded to provide more useful information applicable to all analytical procedures.

Water Section

PART I—"Physical and Chemical Examination of Natural and Treated Water in the Absence of Gross Pollution"—provides many new and improved techniques:

Where data are available, the findings of the Analytical Reference Serv-

ice of the US Public Health Service have been incorporated into the precision and accuracy statements of the common methods because these figures realistically reflect general practice. A writeup on the use of ion-exchange resins in analytical chemistry and in the checking of analyses is included (in the introduction) for the first time.

Acidity. Precision has been introduced into the terminology of the new draft by the use of the terms "methyl orange acidity" and "phenolphthalein acidity" to identify the indicator endpoints. A hot titration in the presence of phenolphthalein indicator has been incorporated in the writeup for the benefit of plants which must treat supplies polluted with acid wastes.

Aluminum. The improved version of the aluminon method is suitable for the colorimetric determination of aluminum in the presence of such common interferences as iron, phosphate, and fluoride. This method has a wider application than its tenth edition counterpart.

Boron. Two colorimetric methods are described—the tenth edition carmine method, which has Standard status, and the new curcumin method, which carries a Tentative designation. The common pH meter and the glass-calomel electrode pair are specified in the potentiometric method.

Bromide. A photometric method based on the formation of an indicator of the bromphenol blue type by the reaction of dilute hypochromite and phenolsulfonephthalein is offered on a Tentative basis.

Calcium. The removal of interferences in the gravimetric and permanganate methods is explained at greater length than in the tenth edition. The EDTA-murexide titrimetric method has been transferred from the hardness to the calcium writeup and accorded Standard status.

Carbon dioxide. Two methods are presented for the determination of carbon dioxide. The tenth edition nomographic method is retained intact. A titrimetric method suitable for field and laboratory applications has been restored to the eleventh edition.

Chloride. The mercuric nitrate method using diphenylcarbazone–xylene cyanol FF indicator has been upgraded to Standard, while the Volhard method has been transferred to the Wastes Section of the eleventh edition. The classical Mohr standard method remains.

Total chromium. The permanganate-precipitation method of the tenth edition has been replaced by the simpler permanganate-azide modification.

Copper. With the deletion of the diethyldithiocarbamate method, the "cuprethol" method is recommended for field and control use in the eleventh edition. An extraction method based on "bathocuproine" reagent is presented for those situations where interference is a problem.

Fluoride. Three important changes have been made in the fluoride writeup. The recently developed direct distillation method has been added under a Tentative heading. A new photometric method based on a zirconium-SPADNS lake also carries a Tentative designation. SPADNS is a dye with the chemical name of 4,5-dihydroxy-3-(*p*-sulfophenylazo)-2,7-naphthalenedisulfonic acid trisodium salt. The Scott-Sanchis and Megregian-Maier colorimetric methods have been retained as standard, while the Lamar method has been deleted.

Hardness. The two standard methods for hardness are: (1) the classical calculation of the hardness from the

calcium and magnesium values; and (2) the EDTA titration with chrome black T indicator in the presence of the ammonia buffer containing a small amount of complexometrically neutral magnesium salt. The soap titration has been deleted.

Iodide. A new photometric method is offered on a Tentative basis. The method entails the addition of ferrous ammonium sulfate for the purpose of arresting the iodine-catalyzed reduction of ceric ion by arsenious acid. The two iodide methods in the tenth edition have been deleted in favor of the simpler direct method.

Iron. The two colorimetric methods in the tenth edition have been retained with minor procedural modifications. The tripyridyl method has been elevated to Standard. An extraction procedure has been added to the writeup.

Lithium. A flame photometric method is presented for the first time, on a Tentative basis.

Methane. Two standard methods are described: the combustible-gas indicator method and the Orsat method.

Nitrate. Major changes have been made in the nitrate draft. A brucine method with Tentative status has replaced the reduction method, which has been deleted. The standard phenoldisulfonic acid method remains, but with a number of minor modifications.

Ammonia and albuminoid nitrogen. The principal changes include the use of EDTA as a stabilizing agent in the direct nesslerization method and the absorption of the ammonia distillate in boric acid.

Organic nitrogen. A mercury catalyst is specified for the Kjeldahl digestion in place of the previous copper salt. Ammonia absorption in boric acid is recommended for all but the smallest nitrogen concentrations.

Ozone. Three standard methods are described: (1) the iodometric method, (2) the orthotolidine-manganous sulfate colorimetric method, and (3) the orthotolidine-arsenite colorimetric method. These methods are designed for the determination of residual ozone in water plants practicing ozonation.

Phosphate. The titrimetric method in the tenth edition has been deleted. The stannous chloride method specifies new concentrations of molybdate reagent and also provides a supplementary extraction procedure for inhibition of interference. The aminonaphthol-sulfonic acid method remains, with minor modifications.

Residue. The more precise terms "filtrable residue" and "nonfiltrable residue" are used in place of the previous "dissolved residue" and "suspended residue." In addition, two drying temperatures (105° and 180°C) are permitted. The ignition temperature in the fixed-residue determination has been raised from the previous 500° to the new 600°C.

Strontium. A flame photometric method is presented for the first time on a Tentative basis.

Sulfate. The versions of the gravimetric method are described. The accurate method specifies the ignition of the barium sulfate precipitate. An alternate gravimetric method, suitable for routine applications, permits the oven-drying of the barium sulfate precipitate before the final weighing. The turbidimetric method specifies a mixed salt-acid reagent containing glycerin. All of these methods have Standard status. The tenth edition titrimetric method using tetrahydroxyquinone indicator has been deleted.

Sulfide. A zinc acetate pretreatment procedure which preserves a sample for subsequent laboratory examination has been added to this writeup.

Anionic surfactants (synthetic detergents). Two methods are offered for the first time, on a Tentative basis, to meet a widespread demand. The methylene blue colorimetric method is satisfactory for general use, while the infrared method is designed for those circumstances where a knowledge of the true alkylbenzenesulfonate content is required.

Taste and odor. Significant changes have been made in this draft. A 200-ml sample is specified for the threshold odor test in place of the previous 250-ml volume. A temperature of 40°C has been specified for the cold threshold odor and a temperature of 60°C for the hot threshold odor.

Zinc. The tenth edition zinc methods have been elevated to Standard status in the eleventh edition.

Other Sections

PART II. Numerous important changes and additions appear in Part II—"Physical and Chemical Examination of Sewage, Treatment Plant Effluents, and Polluted Waters." The more important ones are summarized below:

Residual chlorine. The material has been completely rearranged and rewritten. In the iodometric method, the reducing agent may be either phenylarsenoxide or thiosulfate.

Grease. The solvent has been changed to *n*-hexane and a new adsorption method using alumina to separate the hydrocarbons from the fatty matter of sewage has been added.

Nitrate nitrogen. The brucine method, which seems satisfactory for amounts greater than 1 mg/l, has been added.

PART III—"Examination of Industrial Wastes"—contains a new method for the acidity or alkalinity of wastes such as acid mine waters, providing for the titration of a boiling sample with an alkali or base to the phenolphthalein endpoint.

Cyanide. The tartaric acid distillation procedure in the preliminary treatment of cyanide samples has been omitted.

Metals—chromium. The excess permanganate is removed with azide instead of by boiling with hydrochloric acid. A method for the determination of hexavalent chromium has been added.

Metals—copper. The "neocuproine" method has been substituted for the diethyldithiocarbamate method previously used.

Metals—manganese. The use of persulfate instead of periodate is specified for the oxidation of manganese salts to permanganate.

Phenol. A new method for the determination of para-substituted phenols has been added on a Tentative basis. After use of Gibbs' reagent as a screening procedure, the para-substituted phenols are removed from the sample by steam distillation and reacted with *p*-sulfobenzene-diazonium chloride to form a red dye.

PART IV continues to cover methods for the examination of sludges and bottom sediments.

Volatile acids in sludge. The tentative control methods (*B*) have been improved by centrifuging to remove sludge solids before distillation.

PART V. The growing importance of radioactive pollution of water is recognized by the inclusion in the eleventh edition of a new section, Part V, on

radiologic methods, which gives tentative procedures for the measurement of radioactivity in water and wastes.

PART VI, another new section, is devoted to methods for bioassay of wastes as related to their toxicity to fish.

PART VII. In the section on bacteriologic methods, the membrane filter technique has been made an alternate standard method for the examination of water under specified restrictions as to the general application of this method to routine examinations. The delayed-incubation modification of the membrane filter technique is given as a Tentative procedure. Tentative methods for the detection and enumeration of enterococci are included for the first time. The Most Probable Number tables have been increased to include the usual series of volumes and numbers of portions of the sample examined. Confidence limits are included for each of the MPN values that are likely to be found on examination of samples.

PART VIII. The techniques for the detection of "nuisance bacteria" have been transferred to a separate section—"Iron and Sulfur Bacteria." Tentative methods are described and illustrations included to aid in the identification of the organisms.

PART IX—"Biologic Examination of Water, Sewage, Sludge, and Bottom Materials"—includes new and improved illustrations of significant microorganisms with only minor changes in the technical procedures for these important examinations.

As in all previous editions, the methods and procedures presented in the eleventh edition are based on the best current practices and knowledge in the field of water and waste treatment operations.

Notes and Comment

History of *Standard Methods*

Harry E. Jordan

Consultant to the President of AWWA, Port Washington, N.Y.

Now that the eleventh edition of *Standard Methods for the Examination of Water and Wastewater* is about to be published (see p. 1074 of this issue), it seems appropriate to present a brief outline of the history of this immensely useful manual.

During the convention of the American Public Health Association (APHA) in 1894, a group of men gathered informally to discuss the need for a compilation of the then recognized procedures for the examination of water supply quality. Tradition has it that this informal gathering occurred in a barroom of the Montreal hotel where the convention was being held. Among those present were George W. Fuller, Dr. William Welch of Baltimore, William T. Sedgwick of Boston, Dr. J. G. Adami, and Dr. Wyatt Johnson of Montreal.

This informal gathering was followed by a series of letters, the first of which was written on Jul. 19, 1894, by Adami to Fuller, Welch, Sedgwick, A. C. Abbott, V. C. Vaughn, and Surgeon General Billings. The letter recounted the fact that the group present in Montreal in January 1894 had considered the need of a meeting of minds for the purpose of developing standardized procedures for the examination of water quality.

During a meeting of APHA which took place in Washington, D.C., in 1932, I had the privilege of an extended conversation with George W. Fuller, at which time he made available to me a file of correspondence which he had accumulated in 1895 and in the years immediately thereafter. The correspondence finally brought together a group of the then well known bacteriologists in a meeting in New York, Jun. 21–22, 1895. The meeting was very carefully planned. The group assembled with a series of topics listed for discussion. A formal committee was then organized and charged with the duty of drawing up procedures for the study of bacteria in water. The committee submitted a report at the Philadelphia meeting of APHA in 1897.

Following the conversation I had with Fuller, in 1932, he turned over to me his entire file of this early correspondence, which included the first typewritten draft of the report of the committee submitted at the Philadelphia meeting of APHA in 1897. This assembly of correspondence, now somewhat faded, has been turned over to Dr. Harry P. Kramer of the USPHS Taft Sanitary Engineering Center in Cincinnati, which seems to be the most appropriate location for the preservation of these very early records.

Progress reports were made by the committee in 1900, 1901, and 1902, the first being published in *Science* and the second and third in the APHA proceedings. The first of what may be termed the formal reports of the

committee on the study of methods for water analysis was published in the *Journal of Infectious Diseases* in May 1905. The report of the committee was transmitted by a letter dated Dec. 19, 1904, addressed to the members of the laboratory section of APHA. The submittal was made by a committee consisting of George W. Fuller as chairman, George C. Whipple as secretary, H. W. Clark, Edwin O. Jordan, H. L. Russell, J. W. Ellms, and Robert Spurr Weston. The first 80 pages of the printed text included procedures for physical and chemical examination of water quality. The remaining 60 pages outlined methods for study of the bacteriology of a water sample

The second formal edition of *Standard Methods* was issued in 1913, the chairman of the editorial committee being Earle Phelps. The third edition was issued in 1917 and the fourth in 1920. In the preparation of the fourth edition, a committee representing the American Chemical Society cooperated. In the fifth edition (1923), not only the American Chemical Society, but also AWWA and NEWWA participated.

At the Boston meeting of APHA in 1923, the governing council voted to enter into an agreement with AWWA for joint publication of the book as equal partners. Similar action was taken by AWWA in 1924.

The sixth edition (1925) was prepared jointly by the APHA Committee on Standard Methods (under the chairmanship of Edwin O. Jordan) and the AWWA Council on Standardization (with George W. Fuller as chairman), through its Committee on Standard Methods of Water Analysis (J. J. Hinman Jr., chairman). The seventh edition was published in 1933 under the joint sponsorship of APHA and AWWA, with H. E. Jordan as chairman of the Joint Editorial Committee.

The eighth edition, published in 1936, included the cooperation of a committee appointed by the Water Pollution Control Federation (then called the Federation of Sewage Works Associations); W. D. Hatfield was the chairman of this group. WPCF likewise cooperated in the ninth edition, issued in 1946 under the chairmanship of Dr. John F. Norton. The tenth edition, published in 1955 under the chairmanship of Harry A. Faber, was sponsored by all three associations.

The eleventh edition, to be published next month, is the product of many highly competent workers, directed by the Joint Editorial Board, to which each of the three sponsors appoints a representative. (F. W. Gilcreas of APHA is chairman; WPCF is represented by Gail P. Edwards, and AWWA by Michael J. Taras.) This edition has also benefited from the work of the Joint Committee on Uniformity of Methods of Water Examination (JCUMWE), in which the three publishing partners participate, along with a number of other organizations concerned with water quality. (A report of JCUMWE activities appears on p. 1072 of this issue.)

The history of standardization of water examination procedures has been one of constant progress over a span of more than 60 years. There is every reason to believe that these efforts will meet with continued success in the future.

Questions and Answers on Biologic Infestations

Task Group 2670 P

M. P. Crabill (Chairman), R. J. Becker, R. L. Derby, W. M. Ingram, T. A. Olsen, H. J. Ongerth, C. M. Palmer, C. E. Renn, and J. K. G. Silvey

Presented below are the answers to some typical questions received by Task Group 2670 P from water utility operators confronted with problems of biologic infestations. By collecting information on how such problems have been handled in various localities, the task group may be in a position to suggest practical solutions to operators faced with similar difficulties. Inquiries and experience reports are welcomed and will be kept in strict confidence if desired. Communications may be addressed to: M. P. Crabill, Chairman, Task Group on Biologic Infestation, Indianapolis Water Co., 1220 Speedway Ave., Indianapolis 7, Ind.

Finished Water

QUESTION: We recently acquired several square miles of old distribution system by purchase from a smaller company. Only ground water was supplied through this system. It is planned to substitute surface water by connection to our system. Laboratory examination showed extensive growth of *Crenothrix* in the newly acquired lines. Surface supplies to be substituted do not support the growth of *Crenothrix*. What steps should be taken, if any, with this infestation before the distribution system is put into service?

ANSWER: If possible, the ground water in the old distribution lines should be replaced by the surface water supply about a week before the system is placed in service. The change of supply will cause the *Crenothrix* to slough off owing to the unfavorable composition of the surface water. After several days' contact, extensive flushing should be started until large masses are no longer evident. It would be advisable to follow with heavier chlorination than usual before putting the system in service.

QUESTION: Slime growths thriving in low-flow, low-pressure water distribution mains are often the cause of oxygen depletion and sulfide formation. How are these attached growths eliminated when adequate flushing velocities cannot be effected?

ANSWER: When routine dissolved-oxygen tests show oxygen depletion, the suspected area is isolated by valves and chlorinated to more than 100 ppm and held for a period of 1–2 hr. The mains are then flushed.

QUESTION: Occasionally distribution systems carrying water from wells deliver a tap water that suddenly assumes a hydrogen sulfide odor. In many instances the citizens complain of the existence of a cross connection. It has been observed in certain types of water, particularly those containing iron, that there is adequate population of sulfate organisms and iron organisms growing in the distribution system to induce the production of hydrogen sulfides. This may be particularly true in waters that contain relatively high quantities of chlorides. Frequently the occurrence of hydrogen sulfide is sporadic and more frequent during times of low water consumption. What can be done to correct the situation?

ANSWER: In the South it has been found profitable to use rather high concentrations of combined chlorine, par-

ticularly if the water use is low, as this will give a fairly long contact time and will ultimately reduce the sulfur and iron bacteria as well as counteract the hydrogen sulfide. High chlorine residuals are really more efficient but a rapid kill of these organisms generally results in red water for a few days.

QUESTION: We received consumer complaints of free-swimming animals observed in drinking water. Subsequent investigations indicated *Cyclops* infestation in the system. How can the distribution system be freed of *Cyclops*?

ANSWER: An identical problem was corrected by flushing of mains and following the flushing with an application of cuprichloramine over a 3-week period. This treatment killed *Cyclops* emerging from the eggs which had passed the filters and hatched in the system.

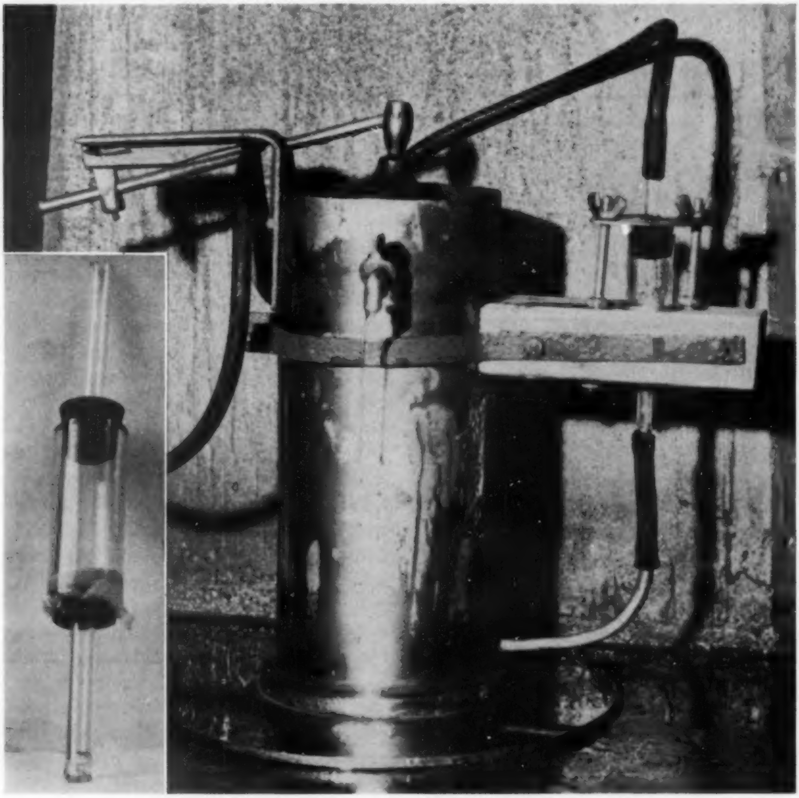


Fig. 1. Simple Device for Biologic Sampling of Filter Effluent

QUESTION: Frequently, finished water leaving a filtration plant will enter the distribution system free of odor. The further the water travels in the distribution system the more intense an odor may become, indicating that the woody, musty, earthy, or marshy odors are evidently originating in the distribution system. What causes it and what is the possible treatment?

ANSWER: During the warmer periods of the year, water containing nutrients may induce a growth of blue-green algae on the interior of the mains carrying water to a city. Actinomycetes, in turn, may grow on the blue-green algae remains and give rise to the odors you mention. This problem is difficult to handle, as chlorine may not affect the actinomycetes in concentrations of less than 10 ppm. Two solutions, however, are possible. If the water is lime softened, the pH can be reduced, removing a part of the deposit and the organisms growing upon it. If water is not softened, the calcium carbonate can be increased slightly, forming a layer over the contamination and thus reducing the odor concentration. Plants equipped with chlorine dioxide equipment may add 2.5 ppm and eradicate the contamination. This should be done in cooperation with agencies familiar with the use of chlorine dioxide, as low residuals are detrimental to fish life and in some instances to laundry processes.

QUESTION: Occasionally an infestation of crustaceans causes complaints of taste and odor in the water distribution system of an unfiltered supply. How are these complaints remedied?

ANSWER: These complaints are usually concentrated in low-flow areas and dead-end mains close to trunk lines, and the odors are usually of a medicinal, iodoform-like nature. When crustacean counts at the reservoir are high, the known crustacean-accumulating areas should be checked for dissolved oxygen depletion, temperature rises, and other indications of flow stagnation and placed on a flushing schedule, some as often as twice a day.

QUESTION: Please give a method of sampling filter effluents to recover either eggs or any organisms that might be passing through the filter media.

ANSWER: A satisfactory sampling device is illustrated in Fig. 1. The thin-walled rubber or plastic tubing shown is connected to a sample cock in the filter effluent pipe. The tube runs between the bracket and the lever arm of the float ball so that the flow from the filter is restricted by pinching the tube as the water level within the chamber raises the float. The tube then extends to the glass nipple in the stopper at the upper end of the filter. The water flows through the biologic filter and is delivered into the main chamber, from which it is discharged through the petcock to waste.

The biologic filter (cutout, Fig. 1) consists of a 2½-in. length of 1-in. diameter pressure gage glass tubing and two rubber stoppers bored for and containing the ¼-in. glass nipples at either end of the filter. The filtering medium consist of ¼ in. of whitewashed sand passing a US series No. 60 screen and retained on a No. 120 screen and a piece of Sedgwick-Rafter cloth of about 200 mesh between the sand and the stopper. Small glass beads in the sand prevent erosion of the sand layer. Assembled and connected, the filter is set to operate at 100 ml/min. After 24 hr of service the filter is removed and the sand is carefully washed in

a small quantity of distilled water, which is then observed under the microscope.

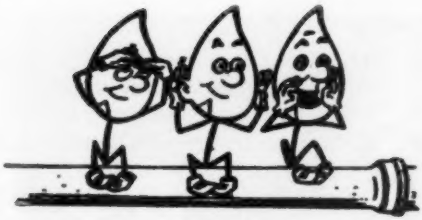
Raw Water

QUESTION: If a raw-water intake pipe becomes reduced in cross section by a rapid buildup of foreign materials so as to reduce the flow 30–40 per cent, what causes the buildup and how can it be controlled?

ANSWER: Frequently caddis flies pass from the raw water into the intake pipe and build up little cases made of sand grains, mud, pieces of debris, or even minute particles of plant remains and glue the cases to the interior of the pipe. Over a period of time the cases pile towards the center of the pipe, ultimately reducing the flow. This may be controlled by adding 5–8 ppm chlorine for 10 min a day.

QUESTION: Am I likely to be troubled with attached clams clogging my raw-water lines from the river to the raw-water settling basins? I have just finished reading about such occurrences in England, the zebra clam, *Dreissensia polymorpha,* being the offender.

ANSWER: You will not be troubled by zebra clams. Fortunately, these clams are not found in the United States. Clams that you may have observed in the river are pearl button clams. Unlike the European zebra clam, they have no holdfasts to cement themselves to pipe, and thus are not capable of living in raw-water conduits or holding themselves in place against the force of pumpage.



Percolation and Runoff

Public concern over water supply seems suddenly to have multiplied until it has become difficult to read a newspaper or magazine without finding some allusion to the importance of water and the need for working now to see that the nation does not thirst in the future. And this is all wonderful, even if we cannot subscribe to all the sweeping statements and jarring generalizations that have been used to elicit the concern. It is, for instance, rather difficult to swallow the news that "we are rapidly approaching the limits of our fresh water supply," as indicated by the Research and Education Committee for a Free World, when we are actually using less than 7 per cent of the total available. Yet we can understand the committee's desire to build up the importance of its generally excellent new brochure, "The Facts About Salt Water Conversion." A little easier to take is the statement of the Milwaukee Co., an investment house, that "steady draining of our national water supplies will make it necessary to cleanse old water for reuse and develop hitherto marginal water resources on a major scale" in the near future. Or even the US Chamber of Commerce report to its members that "water, or the relative lack of it, may well prove to be a No. 1 factor in your future."

But all these and, as a matter of fact, all the other public pronouncements of consequence are concerned with the grand view, the overall picture, the problem, for instance, of providing 600 bgd in 1980 for not only domestic supply, but for irrigation, self-supplied industrial use, and even water power. "Can we double our water supply . . . and quickly?" asks Caterpillar Tractor Co. in an advertisement that takes in the broad picture of flood control and irrigation and reforestation and multipurpose reservoirs and even recreation. And when Lt. Gen. Emerson C. Itschner, chief of the Army engineers, points out that "In general we have sufficient water potentially available to meet growth requirements if we conserve it and keep it clean," he, too, is, of course, taking the broad view, as he and others in similar positions must. Even Everett Partridge of Hagan Chemicals Co., quoted in the March 28 issue of *Barron's*, is speaking of water as a resource in saying: "Our problem for the future is scarcely a lack of water, but rather that it no longer will be virtually free. We shall have to spend more to store, transport, conserve, recondition, and reuse it."

(Continued on page 38 P&R)

(Continued from page 37 P&R)

But to the public water supply field, water is much more specific than a resource and the problem of supplying it is much more pressing than forecasting the needs of 1980 or doing research on the possibilities of desalinization. The general interest of the public is good and is necessary, but what water utilities must do is to focus this general interest upon their own specific problems. And, inasmuch as those problems are really the problems of the public, the task is certainly not an impossible one. If the public can be convinced that its water utilities are willing and able to supply them with all the water they need, when and where they need it, and that this water can be of as high a quality as they demand, the most important step in obtaining public support will have been taken. But perhaps the first step for many utilities will be to convince themselves that such service—adequate in both quantity and quality—is both possible and desirable.

At any rate, people and publications are beginning to manifest an interest in the general problem of water supply and that interest can be used, at any rate by utilities that know what they want, to prime public concern with specific local problems and programs and possibilities. "There's a great day comin'," but it needs "helping on!"

Pool days are here again, and again the growth in pool proprietorship is continuing to exceed the most optimistic estimates. The reasons reported are many:

1. Pool prices are down. New construction techniques have made possible sharp decreases in pool costs, so that a good backyard pool can now be purchased for $2,000–$3,000. And from Detroit comes word that banks are making 5-yr loans for pools with no down payment, making them easier to buy than cars and making auto plant workers, policemen, and teachers the best customers in the area.

2. Public highways are getting more crowded every year, so that travel to beaches has become more and more of a chore. And public beaches have, with increased pollution, usually become less attractive as well. Thus, even those who have not purchased their own pools have in many places turned to public pools or private swimming club pools for their natatory pursuits.

3. With the trend toward suburban living, home sites have increased in size, providing plenty of space for pools. And even though pools must be cared for, they do not have to be mowed.

4. As status symbols, pools have now attained first rank, especially since the levels of automobile ownership have become almost as confused as the social standing of the various brands of cigarets.

5. For the few who want to swim, pools provide an adequate, more convenient plunge than an ocean or lake and for the many who want to display their swimwear and their tans, the pool provides a much more compact theater than any beach.

At this point, it occurs to us to remind ourself that a pool is really only water and not the stuff that encloses it. And the more the pool is appreciated, the more water is appreciated—even if only unconsciously until there is a shortage. So, actually, the ownership of a pool enclosure ought to make a customer support you in supplying all the water he needs, when and where he needs it. Let's all push poolishness.

(Continued on page 40 P&R)

(Continued from page 38 P&R)

Pools can be problems, too, as one was recently for a customer of the Metropolitan Water Dist. of Salt Lake City. Not wanting to drain it when she went away on vacation, she called Chief Engineer Bill Hague for help on keeping children out of her pool during her absence. Bill's reputed suggestion that she get a shark was hardly out of his mouth before it was picked up by a *Saturday Evening Post* cartoonist. Meanwhile, we, who have never heard of a fresh-water shark, must assume that MWD actually does use Great Salt Lake as its source of supply after all. But in other cities, we are now setting up a pool-sitting service, the fees of which will be based on the cost of a refill.

Daniel A. Okun, professor of sanitary engineering, University of North Carolina, will be doing research in the Netherlands during 1960–61, under a fellowship from the National Science Foundation. In October he will attend the 7th European Sanitary Engineering Seminar in Madrid.

David B. Lee (right), director, Bureau of Sanitary Engineering, Florida State Board of Health, meets with representatives of six of the plants that won the board's annual awards for the best operated water plants in the state. Shown above are: Karl Casseur (left), North Palm Beach Water Plant; Williard F. Johnstone, Riviera Beach Water Plant; George Furman, Cocoa Water Plant; Joe Woolfe, Lake Worth Water Plant; C. S. McKinney, Fort Lauderdale Water Plant; and E. C. Burwell, Tampa Water Plant. Representatives from Atlantic Beach Water Plant and Pinellas County Water System were not present.

(Continued on page 42 P&R)

(*Continued from page 40 P&R*)

Willing Water's creator—illustrator-cartoonist Gene Carr—died last December at his home in Walpole, N.H., at the age of 78. Having worked with AWWA to produce its drop-headed supersalesman during the war years, Mr. Carr had for 15 years given Willie spirit as well as shape, personality as well as purpose. Not only Willing Water, but such comic strip characters as "Lady Bountiful," "Phyllis the Servant Girl," "Romeo the Dog," "Flirting Flora," and "Reddy and Caruso" were his creations, together with the strip "All the Comforts of Home" and the cartoon series "Metropolitan Movies." After working for years in newspaper cartooning, Mr. Carr became a freelancer in the 1920's and placed his cartoons in many of the nation's leading magazines, including *The Saturday Evening Post, Redbook, Collier's,* and *Liberty.* In recent years he had drawn primarily for King Features, but Willing Water remained a favorite of his, just as he remained Willing Water's favorite.

Willing Water will miss Gene Carr. He is going to try not to show it too much, and, in fact, has selected a friend of Mr. Carr's—George Wolfe, whose cartooning work is also widely known—to help him keep up appearances. But Willie will remember who breathed life into him and we want to join him in expressing our appreciation of the service that Gene Carr performed for the water supply field in providing a propitious, ambitious "spirit of water service."

Water pressure along political lines has been felt in two areas recently, so far without further result than loss of head:

First, in Toledo, Ohio, the city council, in an attempt to discourage incorporation of its suburban communities, imposed a ban on sales of water to new municipalities some 2 years ago. Inasmuch as the city has the only consequential water system in the county, it expected that the ban would halt the multiplication of local governments. The loss of head, however, followed quickly when opponents, accusing the city of trying to club communities into annexation, went to work on the Board of County Commissioners, succeeding in convincing them that they ought to build a county water system and in getting them to withdraw the sanction already granted to Toledo to annex eleven suburban areas. So the city council voted to lift the ban, despite Mayor Michael Damas' prediction that the result would be encirclement and strangulation of the city's economy and his pointing out that the problem remained "of who is to pay for water lines extended outside the city; the city and county can't, and industries and residents don't want to."

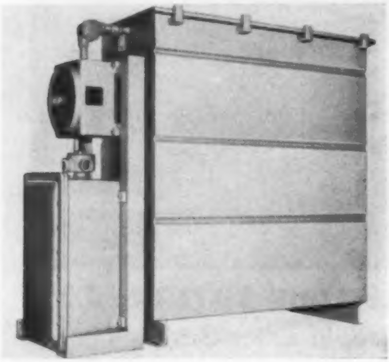
Then, in Missouri, it was the State Water Pollution Board, taking note of Kansas City's failure to act on a required $40,000,000 sewage treatment program, that applied the pressure by ordering the city to cease issuing building permits until it implemented the plan to stop river pollution. And the loss of head was suffered by the city council which voted to defy the board and continue issuing permits attaching new homes to the sewer system that dumps raw sewage into the Missouri River. Now, however, the city is faced with the possibility of federal action through refusal of FHA-insured mortgage loans to builders in

(*Continued on page 44 P&R*)

(Continued from page 42 P&R)

the area—a serious blow to community growth. Meanwhile, downriver at St. Louis, which has a 1967 deadline to provide sewage treatment facilities, the pressure was being felt, too.

It remains to be seen how high a reading there will be on the needling valve.



Automation has been applied to cathodic protection, with the development of an automatic potential control by Electro Rust-Proofing Corp., Belleville, N.J. Because changing conditions affect the rate of corrosion in suberged structures, adjustments in the applied current are required. The new control (see cut) is designed to provide continuous indication of the condition of the structure, as well as regulate the amount of current. It can be adapted to existing cathodic protection systems as well as new ones.

Epilogue to the epidemic at Keene, N.H., where sixteen persons contracted typhoid fever from the public water supply last fall (see February 1960 P&R p. 41), is now being written in dollar signs. Indicated total to date is $67,000, the cost of negotiated settlements with those stricken—$21,000 in medical expenses and loss of pay, $34,000 in pain and suffering, $7,000 in death benefits, and $5,000 in attorneys' fees. The money to cover these settlements is to be raised through short-term loans from local banks which will then be amortized by increasing water rates. All of which would seem to indicate that the cost of planning behind is high.

Charles Kuhn has been appointed president of Dresser Mfg. Div., Bradford, Pa. Formerly vice-president and sales manager, he succeeds F. G. Fabian, Jr., who is now executive vice-president of Dresser Industries.

The Elmira Water Bard is the title earned by Lawrence E. Eyres, secretary-treasurer of the Elmira Water Board, for his lyrical letters. Latest of Larry's rhymed responses was addressed to a Mr. & Mrs. John Gallup, who mistakenly sent their check for sewer service to the water board. Not only they, but all of Elmira, through the columns of the *Star-Gazette,* were put straight on the matter, so:

> To the Gallups,
> No pennies are pinched, no effort is spared,
> In making our water the purest prepared . . .
> And yet there are some who always complain,
> About noisy meters or rust in the main,
> But when YOU confuse our pipes with the sewer
> Our heart is broken and our friends two fewer!

The title, of course, has to be "Ode to the Sewer Department."

(Continued on page 46 P&R)

(Continued from page 44 P&R)

The word is what Pfaudler Permutit, Inc., manufacturers of glass-steel industrial process equipment as well as water treatment equipment and chemicals, is trying to get these days—the word that will properly and pronounceably represent it to the world. Appreciating that the company's present name is neither descriptive nor easy to say or remember, even in English, Pf-P President Donald A. Gaudion, a former employee and admirer of "Kodak," is now looking for a similar type of name, "that can be pronounced in any language, has no bad connotations, and has letters that fit most alphabets." Having coined the word "fluidics" last year to describe its present business, the company does not want its name that limited, as it already has plans for expansion into unfluidic fields. Thus, Gaudion leaned toward meaninglessness in selecting the 55 possibilities that were presented for consideration last month to a group of bilingual employees and foreign students. Out of this linguistic jam session the word "Duratek" emerged as the favorite, but it has since been disqualified for similarity to "Duratech," the name of an all-aluminum boat. And so the search goes on.

Knowing the etymological propensities of some of P&R's readers, we almost hesitate to invite suggestions, but the Gaudion knot must be untied. Volunteers, by the way, are reminded to eschew j's and l's and to keep their ideas characteristically "distinctive and short, and meaningless." Incidentally, we should point out that an almost exemployee has already suggested "Pfit, Inc." And our own brilliant contribution of "Da"—which even babies not only can, but do pronounce

(Continued on page 48 P&R)


3/4"
5/8"
1"
CALMET
1½"
2"

(Continued from page 46 P&R)

—has been rejected not so much on its meaninglessnesslessness, but because it is apparently not an acceptable word in adult Russian.

Joseph F. O'Grady has been appointed by Rockwell Mfg. Co. as assistant vice-president of its Municipal & Utility Div. A member of AWWA since 1952, he is presently a member of the board of governors of WSWMA and chairman of its public relations committee. John G. Hoyt Jr. succeeds him in his former position, product sales manager of the division.

Waistlines for wastelines are what the Philadelphia Water Dept. was seeking last month in soliciting applications for four appointments in the department's Sewer Maintenance Div. The qualifications: that applicants be thin enough to crawl through an 18-in. pipe. The job: "Sewer Crawler." The duties: leak detection, rat hole patching, construction inspection. The idea: Ugh!

Speaking of the waste line, though, we rather resented it as presented by Raymond Loewy, the industrial designer, in a recent discussion of book makeup:

How do we, at present, utilize the surface of a page? Because of blank marginal areas plus open spaces between lines to accommodate ascenders and descenders and between letters, roughly 90 per cent of the area is wasted, and this is too much if our chief concern is efficiency. Incidentally, it is amusing to note that this waste ratio is quite similar to the physical waste ratio of the reader himself, who, as we all know, is 90 per cent water.

"Waste," he says! As far as we're concerned, Loewy can dry up and blow away!

John A. Andrea, chief city engineer, Durham, N.C., was named outstanding graduate of the 1960 course in municipal administration and government, held at the University of North Carolina. His award was presented by the state's League of Municipalities, who selected him from more than 40 municipal employees who completed a 14-week course.

Don Quixote returned last May in the form of a New York City soap salesman named Eugene Friedman. Out for a walk on a sunny day, Gene was approached by a small boy and offered the opportunity to buy a white cardboard box marked "Pyrifer Vaccine Prepared From B. Coli." Remembering from his trusty home medical dictionary that "B. Coli" signified "bacillus cholera," he anxiously broke the seal on the box and had his suspicions more than confirmed by the sight of ten ampules, each marked "1,000,000,000 Germs." Giving the boy a quarter, he hurried home to his dictionary and read himself into a cold sweat on the subject of cholera. Then, to save the city from total catastrophe, he rushed out, with his box held gingerly in front of him, carrying it first

(Continued on page 50 P&R)

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(Continued from page 48 P&R)

to two nearby physicians, who had neither the time nor the inclination to humor him. Then he called the police and they referred him to the health department. And they, having heard what the label said, summarily de-agitated him with the news that the germs in the vaccine were dead to begin with and now worthless as well, probably having been discarded by some doctor.

So what if he didn't save the metropolis from extinction by cholera? Could you have bought more thrills for a quarter?

Frank W. Melcher, senior staff chemist for water treatment, analysis, and research, Coca-Cola Co., Atlanta, received an award from the Society of Soft Drink Technologists for the paper that made the best contribution to soft-drink technology during 1959. The subject of the paper was the operation and cleaning of sand filters.

Kingfish is what his friends are calling Ben Nesin, director of laboratories for the New York City water department, these days. Kingfish it has been since Ben, with great reluctance, proved last May at Bal Harbour that with salt water, as with fresh, he knew what was in it and knew how to get it out. He must have baited his hook with a nematode, though, to land a 45-lb kingfish as his first deep-water catch.

(Continued on page 51 P&R)

(Continued from page 51 P&R)

Arthur P. Miller, sanitary engineer director, USPHS, retired on May 31, 1960, after serving with the agency for almost 40 years. A member of AWWA since 1920, he is a Life Member. He has also been active in APHA, WPCF, and ASCE.

Clarence K. Hood, vice-president, Worthington Corp., Harrison, N.J., retired on Apr. 29, 1960, after 42 years of service with the company. Since 1952 he has been manager of public works sales.

Malcolm Pirnie Engineers announces the appointment of Alfred C. Leonard as a partner in the firm, after several years of service as an associate engineer.

(Continued on page 52 P&R)

(Continued from page 50 P&R)

George A. Kendall, president, Palos Verdes (Calif.) Water Co., died Jun. 14, 1960, at his home in Palos Verdes, at the age of 54. He had been president and AWWA corporate representative of the utility since its establishment in 1954, and was also a director of the Diamond Bar Water Co., Pomona, Calif.

Robert E. McDonnell, senior member, Burns & McDonnell Engineering Co., Kansas City, Mo., died Jan. 2, 1960, at the age of 87. Born in Gallatin County, Mont., in 1872, he received his degree in civil engineering from Stanford University in 1897. He and Clinton S. Burns founded the consulting engineering firm of Burns & McDonnell in April 1898. He retired in 1948, on the 50th anniversary of the company. A member of AWWA since 1913, he was a Life Member. Other professional affiliations included ASCE (life member) and Engineers Club of Kansas City, in which he served as president in 1927.

W. Luther Stothoff, president, William Stothoff Co., Inc., Flemington, N.J., died Apr. 21, 1960, at the age of 73. A lifelong resident of Flemington, he succeeded his father, founder of the well-drilling firm, as president. He was a member of AWWA since 1942.

W. T. Tarbell, city engineer of Fargo, N.D., since 1927, died on Jun. 3, 1960, at Fargo. A member of AWWA since 1928, he was formerly chairman of the old Minnesota Section and a Life Member of the Association.

Correspondence

The Better 25.6%

To the Editor:

From the June *Willing Water* breakdown of Bal Harbour registration I have calculated the percentage of registrants who were ladies, as follows:

	Men	Ladies	Percentage
1960 (Bal Harbour)	2157	879	25.6
1959 (San Francisco)	2426	785	24.4
1958 (Dallas)	2337	687	22.4

It will be noted that the percentage of ladies attending the AWWA meetings is on the increase at the rate of 1.2–1.6 per cent per year, which certainly is a very healthy sign.

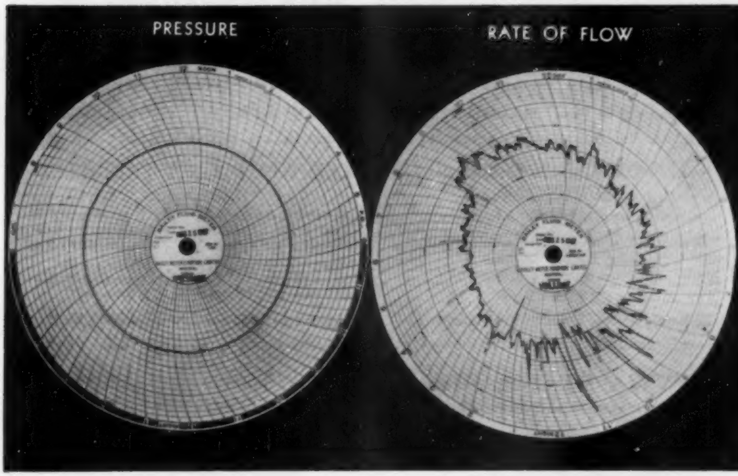
On this basis of increase I estimate that sometime around 1975 or 1980 there will be more ladies than men attending annual AWWA meetings. Certainly this is a beautiful prospect for some of our younger generation attending future AWWA meetings. For some of us oldsters we can only hope that we will live that long.

In any case, these statistics are extremely interesting and perhaps some of your statistical friends can make more of them than I can.

E. A. Sigworth

New York; Jun. 9, 1960

As a matter of fact, we did notice an unusual interest in female statistics at Bal Harbour.—Ed.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Professional Services

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Professional Services

Professional Services

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Condensation

Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene* (*Great Britain*)*; CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals* (*Great Britain*)*; PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts* (*Great Britain*).

AQUATIC ORGANISMS

The Oxygen Consumption of *Artemia salina* (L.). B. M. GILCHRIST. *Hydrobiologia,* 12:27 ('58). Expts. have previously been made on the oxygen consumption of females of *Artemia salina* in water of different salinities, and further expts. have now been carried out on the oxygen consumption of male *Artemia* reared in sea water (salinity 35 per 1,000) and concd. brine (salinity 140 per 1,000). The tot. oxygen consumption was found to be related to the 0.883 and 0.624 power of the dry wt. for animals reared in sea water and brine respectively. The increase in oxygen consumption with increasing size was significantly greater in sea water than in more concd. brine, and this appears to be related to the larger area of the 2nd antennae of males reared in sea water. In concd. brine, there is no difference between the amt. and rate of oxygen uptake of males and females, but in sea water the oxygen consumption of males increases more rapidly than that of females with increasing size of the animals.—*WPA*

Preliminary Observations on the Oxygen Uptake by Some Fresh Water Zooplankters. R. A. VOLLENWEIDER & O. RAVERA. *Verhandl. Intern. Ver. Limnologie* (Ger.), 13:590 ('58). Prelim. results are presented from investns. on the factors which affect the rate of oxygen consumption by planktonic fresh-water animals. In lab. expts. with *Daphnia obtusa,* no crowding effect occurred with up to 350 individuals per liter, and the mean oxygen consumption at 15°C was 4.05 ± 0.20 μg per individual per 24 hr. Metabolic activity decreased during the course of starvation and also appeared to be inhibited by senescent *Chlorella* cultures used as a source of food. The variations in oxygen consumption during the growth and maturation of *Daphnia obtusa* are shown graphically; the oxygen consumption is related to the instar, the body size, and the age. A direct relation was found between the oxygen consumption and the temp. of the water, and the temp. coefs. for various species are shown graphically. The results obtained were used in measurements of the oxygen consumption by the pops. of lakes Maggiore and Mergozzo.—*WPA*

Sodium Uptake by the Crayfish. J. SHAW. *Nature* (Lond.), 182:1105 ('58). The author describes studies carried out to find the effect of variation in internal and external sodium concn. on the rate of uptake of sodium in the fresh-water crayfish, *Astacus pallipes.* These studies show that sodium uptake in the crayfish takes place by a mechanism which is highly regulated and well adapted to maintain the animal in sodium balance. Although the rate of uptake is sensitive to changes in the external concn., at the concns. found in tap water, any resulting change in the internal sodium concn. brings about a change in the uptake rate in the opposite direction and a self-balancing system results.—*WPA*

Resistance of Fresh-Water Crustaceans to the Action of Sodium Chromate. P. J. LAURENT. *Verhandl. Intern. Ver. Limnologie* (Ger.), 13:590 ('58). In studies to investigate organisms requiring a shorter duration of toxicity test than fish, it was found impossible to use *Asellus,* owing to cannibalism of groups in captivity and excessive mortality when the individual organisms were isolated. The results of tests with *Gammarus pulex pulex* were more satisfactory and are shown graphically. In a soln. contg. 85 mg/l sodium chromate, tot. mortality occurred after 2 hr 40 min, and with a dose of 4.3 mg/l after 68 hr 30 min. In these two solns., the greatest mortality occurred after 13 hr 10 min and 24 hr

(*Continued on page 66 P&R*)

(*Continued from page 64 P&R*)

25 min, respectively. The delay before the first signs of intoxication was not, however, related to the concn. of chromate. When the time of greatest mortality was plotted against concn., both on logarithmic scales, a straight line was obtained, in the range 4.3–8.5 mg/l chromate. Further expts. will be undertaken to compare the resistance of *Gammarus* to sodium chromate with that of fish.—*WPA*

The Brackish-Water Tolerance of Some Fresh Water Crustaceans. K. Lagerspetz. *Verhandl. Intern. Ver. Limnologie* (Ger.), 13:718 ('58). In expts. on the brackish-water tolerance of *Daphnia*, it was found that *D. magna* could breed and develop in brackish water and even withstand water of salinity 5.8 per 1,000, whereas *D. pulex* and *D. longispina* showed a high mortality at a salinity of 2.9 per 1,000. When *Asellus* species collected from a rock pool (salinity 0.8 per 1,000) and from *Fucus* vegetation in the sea (salinity 4.9 per 1,000) were transferred to sea water (4.9 per 1,000) or fresh well water (less than 0.03 per 1,000), all specimens survived well except the brackish-water animals transferred to fresh water. Further investns. are necessary to explain the differences in the response of these fresh-water animals to brackish water.—*WPA*

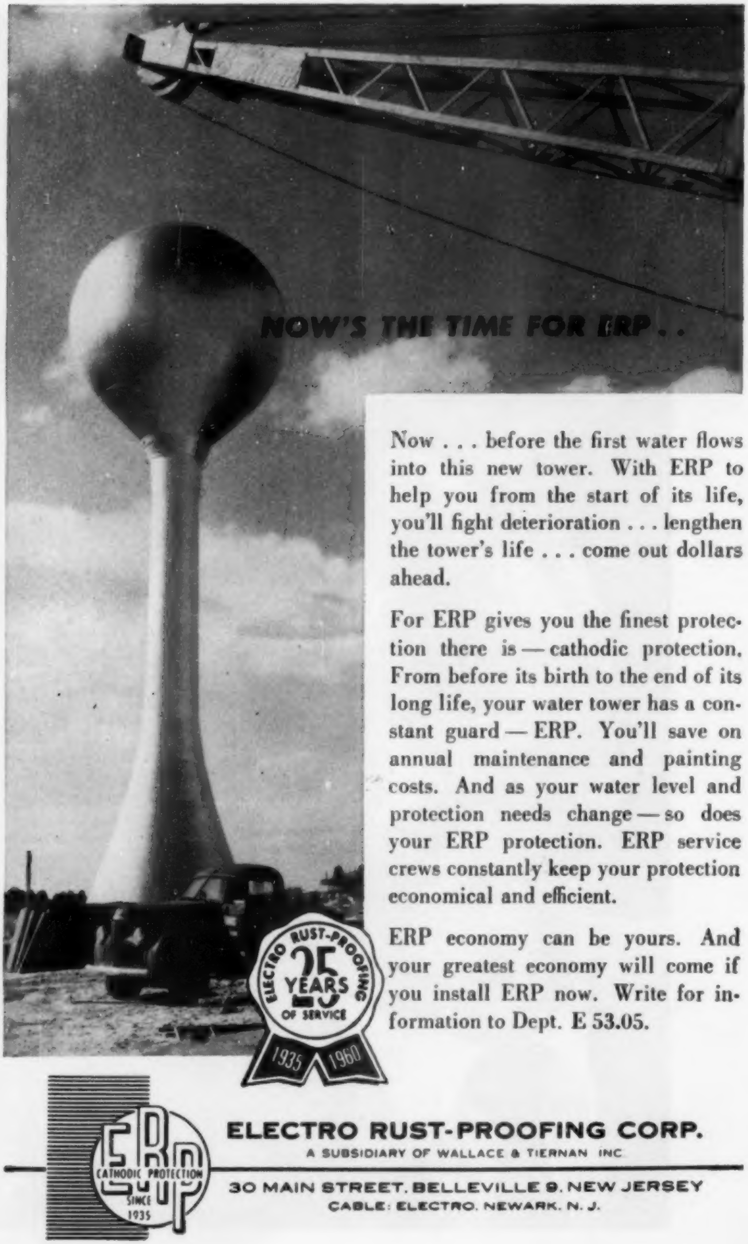
A Study of Plankton Copepod Communities in the Columbia Basin, Southeastern Washington. R. H. Whittaker & C. W. Fairbanks. *Ecology*, 39:46 ('58). A study has been carried out on plankton copepod communities in stream channels and lakes in the Columbia Basin, Southeastern Washington. The relation between species and the salinity gradient was investd. and the results are given; attempts to establish the effects of various metallic ions on species pops. and plankton community types gave inconclusive but generally negative results. Productivity increased with increasing salinity in both lakes and ponds through most of the range of salinity conditions sampled; microcrustacean pops. per unit volume of water were almost twice as high in ponds as in lakes. A matrix and plexus for plankton samples and community types, prepared by measurements of percentage similarities, are described and distributional relations of copepod species are summarized.—*WPA*

On the Preference of Roaches (*Leuciscus rutilus*) for Trinitrophenol, Studied With the Fluviarium Technique. P. E. Lindahl & A. Marcstroem. *J. Fisheries Research Board Can.*, 15:685 ('58). An illustrated description is given of apparatus developed for testing the reactions of fish to solns. with a reproducible and well-defined concn. gradient, and the results of expts. on the response of roach to concns. of 2,4,6-trinitrophenol are discussed. It was found that the fish showed a preference for water contg. trinitrophenol, and prolonged their stay in the higher concns. of the chemical; however, concns. greater than $27.5 \times 10^{-5}M$ appeared to be repellent, and fish in this soln. showed signs of distress. The responsiveness of the fish varied considerably and appeared to be affected by length as well as age, smaller fish reacting more rapidly than larger ones and older fish more promptly than younger ones.—*WPA*

Contribution to the Ecology of Some Ciliates in the Saprobic System. H. Bick. *Vom Wasser* (Ger.), 24:224 ('57). The author describes investns. into the effect on the ciliate pop. of the composition of the water. The investns. were made in small natural waters, most of which received large amts. of fallen leaves, and in the lab. in water contg. decompn. products of cellulose. The chem. composition of habitats suitable for a large number of ciliate types is described, limiting values being given for pH value and contents of oxygen, nitrite, nitrate, ammonia, and hydrogen sulfide. The author then deals with the effects of oxygen and hydrogen sulfide, giving diagrams showing the toleration of 14 types of ciliates.—*WPA*

Preferred Temperature of Rainbow Trout (*Salmo gairdneri* Richardson) and Its Unusual Relationship to Acclimation Temperature. E. T. Garside & J. S. Tait. *Can. J. Zool.*, 36:563 ('58). In most species of fish, the selected or preferred temp. is directly related to increasing acclimation temp. Expts. have now shown, however, that in the rainbow trout (*Salmo gairdneri*) the preferred temp. decreases with increase in acclimation temp. The modal preferred temp. of trout acclimated to 5°, 10°, 15° and 20°C were determined photographically to be 16°, 15°, 13° and 11°, respectively.—*WPA*

(*Continued on page 70 P&R*)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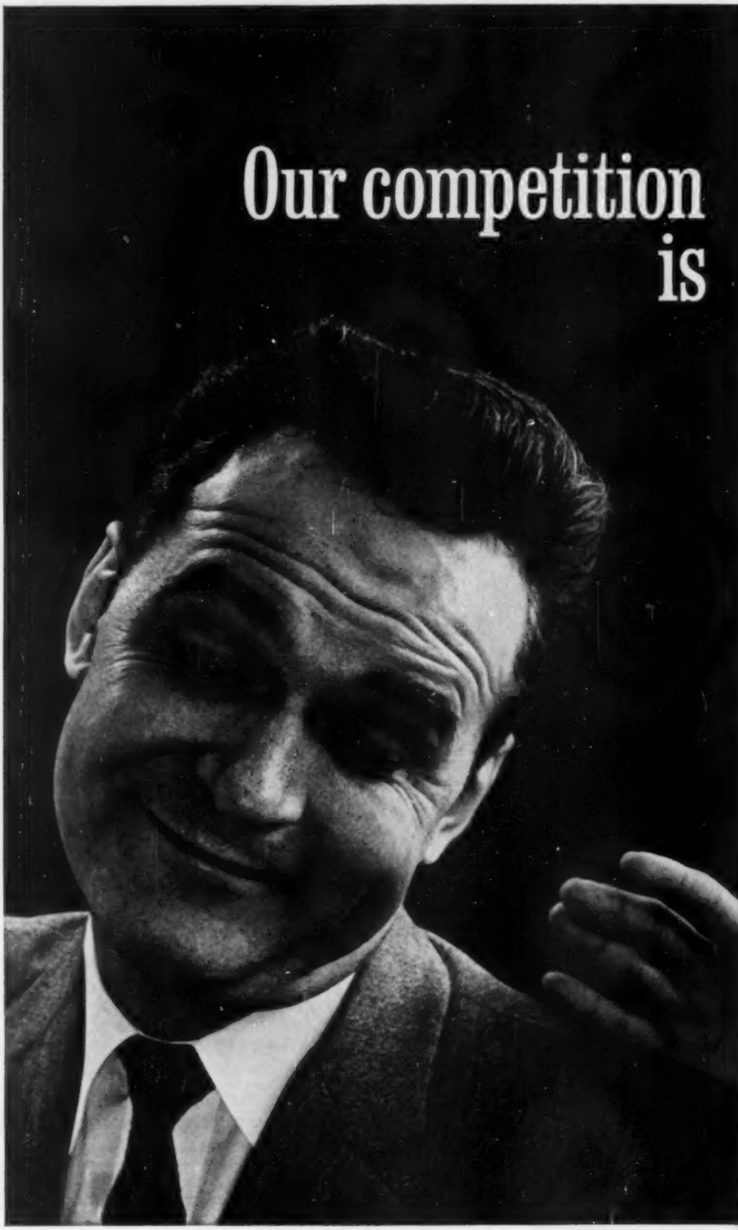
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(Continued from page 66 P&R)

Experiments on Control of the Mussel *Dreissensia polymorpha* Pallas by Ultrasonic Treatment. G. BREITIG. *Literturber. Wasser, Abwasser, Luft & Boden* (Ger.), 7:83 ('58). The mussel *Dreissensia* frequently causes trouble in water works and cooling-water supply plants. The free-swimming larvae are too small to be removed by screening. Expts. on the effect of ultrasonic waves and the apparatus used are described. A selective action on plant and animal plankton organisms, with a high destruction of *Dreissensia* larvae, was observed. The possibility of development of the process for technical use on a large scale is discussed.—*WPA*

BACTERIOLOGY

The Effect of Various Water Bacteria on the Growth of *Escherichia coli* I in MacConkey's Broth at 37°C and 42°C. R. ETINGER-TULCZYNSKA. *J. Appl. Bacteriology*, 21:2:174 ('58). Mixed cultures of *E. coli* I and various other bacteria isolated from water were studied. A streptomycin resistant *E. coli* I strain was used for ease of differentiations from other organisms. Species of *Achromobacter*, *Micrococcus*, *Proteus* and *Pseudomonas* did not significantly affect growth of *E. coli*. *Achromobacter* and *Micrococcus* died out, *Proteus* survived in small numbers and *Pseudomonas* multiplied in the 24-hr incubation period. Other coli-aerogenes bacteria *Klebsiella* [*Cloaca*] *cloaccae*, *K. aerogenes* and *Citrobacter freundii* did, however, cause some retardation or inhibition of growth of *E. coli* I at 37°C, especially when initially present in very much larger numbers, although in all cases *E. coli* I was still recoverable. At 42°C, the interfering action of *C. freundii* was much less marked. When mixtures of several organisms were grown in association with *E. coli* I the strongest inhibitor exerted its usual effect. The effect of this interference with growth of *E. coli* I on its ultimate recovery from a sample will depend on the efficiency of the technique used to confirm the presence of *E. coli* I in the primary culture.—*BH*

(Continued on page 72 P&R)

This ion exchange unit deionizes boiler make-up water at Crown Zellerbach paper mill, Bogalusa, Louisiana.

AMBERLITE ion exchange resins remove silica and other ionized impurities from make-up water for high pressure boilers at the Bogalusa Mill of the Crown Zellerbach Corporation. Steam at 900 psi drives power generator turbines. Effluent steam is piped to paper-machine dryers.

To furnish the make-up, well water containing the high silica level of 30 ppm is fed to a two-bed deionizing system having 127 cubic feet of AMBERLITE IR-120 in the cation exchanger and 207 cubic feet of AMBERLITE IRA-400 in the anion exchange unit. Ion exchange treatment reduces silica content to 0.20 ppm and conductivity to 4 micromhos.

Flow rate is 350 gallons per minute. Design specifications call for regeneration of the ion exchange beds after treatment of 505,000 gallons of water. However, the high capacity of the ion exchange resins permits the units to run far beyond this limit.

AMBERLITE ion exchange resins have solved many commercial problems, such as recovery of costly metals from industrial wastes, removal of contaminants from chemicals, and extraction of pharmaceuticals from reaction mixtures. Write for our booklets *Ion Exchange with the* AMBERLITE *Resins* and *If You Use Water.*

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THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.

(*Continued from page 70 P&R*)

Observations on the Growth in Nutrient Broth of Mixtures of *Escherichia coli* Strains, and of Fecal Specimens Harboring Pathogenic *Escherichia coli* Serotypes. J. M. DIXON. *J. Hyg.*, 57:174 ('59). Expts. on the competitive growth of mixed *Coli* cultures in nutrient broth were made using 5 pathogenic serotypes and 5 nonpathogenic *Esch. coli* strains. In mixts. incubated at either 37° or 44°C, the organism inoculated in smallest numbers increased proportionately after incubation for 18 hr or more; the greater the initial disparity the greater was the increase. Broth culture favored the pathogenic strains only when these were numerically inferior in the inoculum. A study was made of the use of nutrient broth in the isolation of pathogenic *Esch. coli* strains from the feces of infants. It is concluded that the main value of nutrient broth as an enrichment method is in the examination of the feces of suspected carriers and convalescent patients, in which the pathogen is likely to be outnumbered by nonpathogenic *Esch. coli* strains.—*WPA*

Possible Explanations for the Inhibitory Action of Boric Acid Lactose Broth at 43°C on Fecal Coliform Bacteria. C. E. SKINNER & A. N. OBI. *Appl. Microbiol.*, 6:289 ('58). It has been shown that the most probable number of fecal coliform bacteria is considerably higher when counts are made by dilution extinction methods in standard lactose broth at 35°C than when boric acid lactose broth at 43°C is used. Various theories have been suggested to explain this, and the authors have now investigated some of these. It is concluded that either only a portion of the cells of any pop. of *Esch. coli* is able to initiate growth in unfavorable media such as boric acid lactose broth at 43°C, or that several cells of *Esch. coli* are necessary to initiate growth in this medium. Both these theories are compatible with known data.—*WPA*

The Value of the Enterococcus Test in the Examination of Drinking and Surface Waters. O. GUTHOF & G. DAMMANN. *Arch. Hyg. u. Bakteriol.* (Ger.), 142:7:559 ('58). Tests for enterococci constitute a worthwhile addition to the bact. examn. of water. In the selection of suitable media the sodium azide content and the pH are of decisive importance. In an acid medium sodium azide is a poor selective agent, but a good one under alkaline conditions. The selective action in alkaline conditions can be made still better by a higher sodium chloride concentration. Enterococci are not damaged at a pH of 8.3 in sodium-azide-sodium-chloride medium whereas *Escherichia* and coliform bacteria are completely eliminated and spore-bearers largely suppressed. False positive results in 1-stage procedures were found to be mostly due to an enterococcus-like air organism, the diplococcus I. Plating out can be done by incubating at 45°C on crystal violet or ethyl violet confirmatory medium, or by the differentiating action of a selenite plate. A 2-stage method for the cultivation of enterococci is described. First a primary culture is made on dextrose broth at pH 8.3 containing 0.03% sodium azide and 3% sodium chloride and this is followed by subculture on a selenite plate. The authors conclude that the enterococcus test is easy to perform and of particular value in assessing the significance of coliform counts. They recommend its adoption as a worthwhile addition to the routine bacteriological examination of water samples. 100 water samples from springs with varying *Coli* counts were investigated simultaneously for *Escherichia* and enterococci. A close agreement is shown in the results. Also in 80 samples of Rhine water taken on different days and from different places approximately similar enterococci and *Coli* titers were found.—*BH*

Enumeration of Bacteria in Liquid Media—Application to the Estimation of Coliform Organisms in Water by a Statistical Method. R. BOUILLAUD. *Rev. Hyg. et Med. Sociale* (Paris), 6:7:731 ('58). The author describes the mathematical principles underlying the estn. of numbers of coliform organisms by the "most probable number" method. He then proposes a routine method for measuring poln. of water by dividing 100 ml of water into 8 portions of varying amts., culturing and subculturing the positive tubes or flasks to identify the type of organism. Waters contg. fecal *Esch. coli* are rejected, and the poln. of other water is measured by calcg. the most probable number of *Clostridium welchii* and enterococci.—*BH*

(*Continued on page 74 P&R*)

(*Continued from page 72 P&R*)

On Some of the Characteristics of the Substance in Underground Water Affecting the Survival of Salmonella Organisms. R. Meyer. *Arch. Hyg. u. Bakteriol.* (Ger.), 143:5:334 ('59). The question is discussed whether the death of salmonella organisms in underground water is due in the main to absence of nutritive factors or the presence of some lethal agent. The survival of inoculae of *Salm. typhi* and *Salm. paratyphi B* was estimated in samples of raw well water, after coagulation and filtration and from the water tower immediately before going into supply in the town of Aurich. It is concluded that the deep well water contains an agent causing the death of *Salm. typhi* and *Salm. paratyphi B.* This substance resists boiling and is probably filtrable; it can be adsorbed on and eluted from ferric hydroxide, does not show any oligodynamic action and will inhibit the growth of the organisms in question when it is diluted with broth from 10^{-3} up to 10^{-4}. —*BH*

On the Determination of the Salmonella Quotient in the Bacteriological Examination of Water. R. Meyer. *Arch. Hyg. u. Bakteriol.* (Ger.), 143:3:221 ('59). Samples of deep well water from Aurich were inoculated with suspensions of *Salmonella typhi* and *Salm. paratyphi B* and incubated at 7°C, 20°C, and 37°C. The surviving bacteria were then estd. after 24 hr. With *Salm. typhi* a bactericidal effect was noticed at all temps. and in samples from all stages of the purification process. In the case of *Salm. paratyphi B* there was a tendency for the bacteria to multiply in the raw and partially purified water in the samples incubated at 37°C only. The opposite effect was seen in the filtered water. This was thought to be associated with the iron content, the raw water being rich in iron. The bactericidal effect could not be correlated with any particular chemical factor. The natural antibact. power of the water was found to vary from time to time and it is suggested that estn. of the "*Salmonella*" quotient" (*Keimverminderungsquotient*) should

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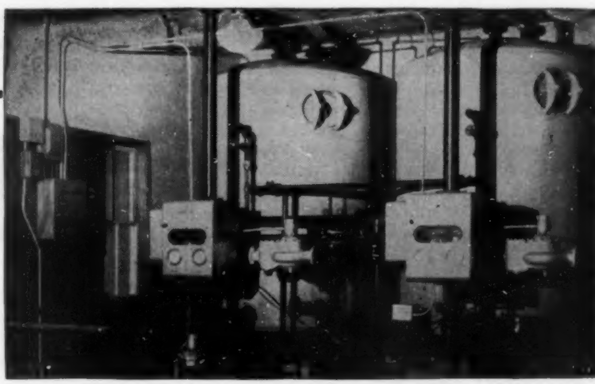

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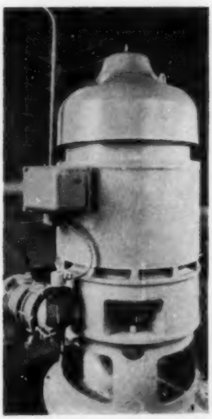

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(*Continued from page 74 P&R*)

be regarded as a necessary supplement to the usual methods of water examination.—*BH*

The Membrane Filter Technique for Estimating Numbers of Viable Bacteria: Some Observed Limitations With Certain Species. H. Wolochow. *Appl. Microbiol.*, 6:201 ('58). Expts. on the membrane filter method for counting viable bacteria have shown that the method is not reliable when certain organisms are tested. None of the factors investigated—concn. of medium, vol. of medium in the nutrient pad, comparison of variation between lots of filters, humidity, and age of suspension before filtration—appeared to be responsible for the observed variability. It is pointed out that culture media devised for other uses may not always be satisfactory for use with membrane filters. —*WPA*

The Detection of Fecal Streptococci in Drinking Water. P. Spaander & A. C. Roest. *Antonie van Leeuwenhoek: J. Microbiol. & Serol.* (Neth.), 25:2:169 ('59). The difficulties in interpretation of differential tests for enterococci are outlined. Many of the difficulties associated with the Sherman tests are considered to arise because many of these are marginal tests. In the Netherlands the production of black colonies on sorbitol-tellurite-agar is recommended as a differential test, but this is sometimes doubtful in interpretation when colonies of all shades of gray are produced. A citrate utilization test is recommended as an additional criterion in doubtful cases. A peptone water containing 1% sodium citrate at pH 7.4 is incubated at 37°C for 48 hr. On adding 0.5 ml of saturated lead acetate soln. to 3 and 4 ml of the culture a heavy ppt. occurs if the citrate has not been utilized and only a slight ppt. if the citrate has been utilized. Tests with 55 known enterococcus strains gave positive results with all varieties of *Streptococcus faecalis*, negative results with *Str. bovis*, *Str. durans* and *Str. lactis*, and variable results with *Str. faecium*. Of 8 strains of the latter examined, 7 grew with gray colonies on the tellurite agar, 5 of which were negative on citrate and 2 positive. The examn. of 200 strains of aquatic streptococci indicated that citrate utilization in conjunction with sorbitol-tellurite-agar enabled a reliable interpretation of fecal streptococci to be made.—*BH*

The Loss of Viability of Bacteria in Suspension Due to Changing the Ionic Environment. B. S. Gossling. *J. Appl. Bacteriol.*, 21:220 ('58). Following the accidental discovery and subsequent confirmation of an 80% loss of viability in a suspension of *Escherichia coli* when the ionic environment was changed from phosphate buffer to Ringer's soln., and of similar losses after changes in the reverse direction, the behavior of other organisms was studied. *Clostridium butyricum, Streptococcus lactis, Escherichia coli,* and *Micrococcus candidus* gave positive results; *Mycobacaerium smegmatis* and a brewer's yeast did not. The survey included variations in the conditions, mostly with *E. coli*. Minor constituents of the solns. or alteration of their pH modified the effect—that of 1% NaCl in place of Ringer's soln., or of pH 8.0 instead of the usual pH 7.2, was quite different. Also, the addn. of glucose, sodium thioglycollate, or methylene blue diminished it, with one exception in the case of glucose. *Mic. candidus* responded if the solns. were chilled, but not at room temp. With electrolyte concns. below about 0.02*M* there was no effect. Various other changes of anions were effective, as also was change from a univalent to a bivalent cation. A second treatment, following the necessary intermediate reverse change which had no effect, caused another smaller mortality. This reduced sensitivity gave a diminished loss which persisted through many subsequent subculturings.—*PHEA*

Utilization of Thiocyanate by *Thiobacillus thioparus* and *T. thiocyanoxidans*. F. Happold; G. Jones; & D. Pratt. *Nature* (Lond.), 182:266 ('58). *Thiobacillus thioparus* and *Thiobacillus thiocyanoxidans* were grown at 30°C on thiosulfate or thiocyanate media to compare the ability of the 2 orgs. to utilize both thiocyanate and thiosulfate for growth. The results suggest that *T. thioparus* has a similar or identical capacity with *T. thiocyanoxidans* for growing on thiocyanate. This result was confirmed by serial dilution tests (dilution in the range 1/30 to 1/24 300 000) in which the cultures were incubated for 10 days after dilution and back-inoculated into both thiosulfate and

(*Continued on page 78 P&R*)

(Continued from page 76 P&R)

thiocyanate. The rate of growth of viable cells of *T. thiocyanoxidans* at 30°C in thiocyanate medium is shown graphically and compared with the concurrent rate of disappearance of thiocyanate; the viable cell pop. did not increase much after 48 hr, when about 20% of the substrate had disappeared. Cell autolysis is rapid with an abundant liberation of amino acids and growth factors into the medium, so that many heterotrophs can grow in the supernatants which remain after the culture has apparently become sterile. In manometric expts. to investigate the oxidation of various organic substrates by *T. thiocyanoxidans,* very little oxidation of formate or succinate occurred when the cells were grown on a thiosulfate medium, but there was a marked increase in oxidation when grown on a thiocyanate medium. When the cell suspension had a very high endogenous respiration, other substrates such as pyruvate have been oxidized. Colorimetric evidence has suggested that small amts. of formate may appear in cultures when growing on a thiocyanate medium.—*WPA*

A Study of the Size of Bacterial Populations and of Organic Matter Formation Due to Photo- and Chemosynthesis in Water Bodies of Different Types. S. I. Kuznetsov. *Verhandl. Intern. Ver. Limnologie* (Ger.), 13:156 ('58). In studies of the distribution of microorganisms in lakes of various types in the Soviet Union, direct microscopic counts were made, and the percentage of dead cells was estd. by a staining technique. The dead bacteria constituted about 10% of the tot. no. The results, which are given in tables and graphs, showed that the distribution of bacteria was related to the lake type and to the distribution of phytoplankton. High counts of bacteria were obtained when the phytoplankton had recently been dense. The no. of bacteria in the bottom muds was also related to the trophy of the lakes; the nos. decreased markedly with depth of mud. Data are also tabulated on the rate of multiplication of the bacteria in the different lakes and the role of microorganisms in the turnover clarifica-

(Continued on page 80 P&R)

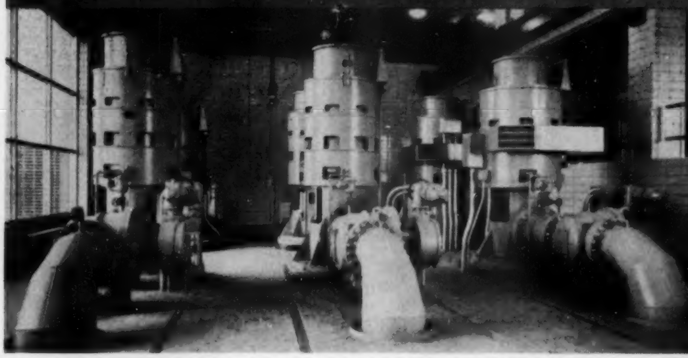
(*Continued from page 78 P&R*)

tion. The water is demineralized by ion exchange, carbon dioxide is removed in an air-blown packed tower, and the pH is raised to 7.0–7.5 with caustic soda. The water is further conditioned with hydrazine and sodium phosphate.—*WPA*

Coliform Organisms in Domestic Water Supplies in Ceylon. D. C. Katugampola & T. H. Assim. *Ceylon J. Med. Sci.*, 9:2: 95 ('58). The possibility of differentiating *Esch. coli* from coliform organisms by using MacConkey broth or brilliant green bile broth at 44°C in conjunction with indole tests at 44°C was studied on 153 water samples in Ceylon. Of the samples giving positive results at 44°C on MacConkey broth only 50% were *E. coli* I and similarly with BGB only 55.5% were *E. coli* I. *Klebsiella aerogenes* I accounted for 77% and 58% respectively of the remainder. Of other types all those which gave indole at 37°C also produced it at 44°C, namely *K. aerogenes* II, *Citrobacter freundii* II and Irregular VII. These formed 8% of the tot. colonies fermenting lactose at 44°C. Under Ceylon conditions, therefore, a combined test using fermentation of lactose and indole production at 44°C does not differentiate *E. coli* I absolutely from other coliform organisms. The high proportion of *K. aerogenes* I strains positive at 44°C may be due to their possible fecal origin in the tropics or to environmental and climatic adaptation of the organism outside the body. Standards for evaluation of tropical water supplies will not be satisfactory without further knowledge of the significance of these organisms. —*BH*

Selective Enrichment Medium for Paratyphoid Bacteria—Inhibitory and Growth-Promoting Factors. F. Rappaport & N. Konforti. *Appl. Microbiol.*, 7:63 ('59). An enrichment medium has previously been developed for the isolation of Salmonellae of the paratyphoid group; this medium contains Bacto-Tryptone, sodium chloride, potassium dihydrogen phosphate, malachite

(*Continued on page 84 P&R*)



Water Purification At Glen

Water treatment facilities for Page, Arizona, at Glen Canyon Dam, include two 60-ft. diameter Eimco-Process Reactor-Clarifiers: one for pre-sedimentation of Colorado River water; one for final clarification.

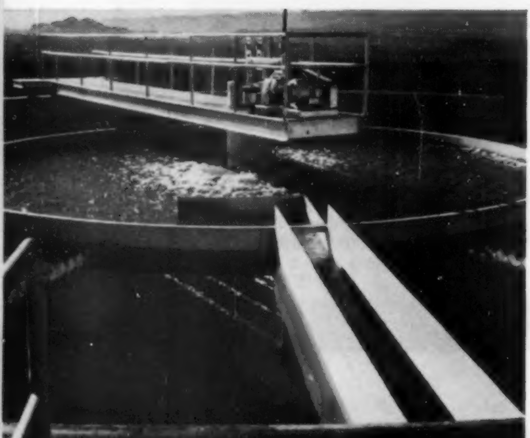
To handle the tons of sand and silt contained in the raw river water, the 1.5 MGD pre-sedimentation unit at the river is equipped with a mechanism that continuously scrapes deposited solids to a central discharge. Coagulation of silt is aided by recirculating sludge with air. A skimmer removes floating debris. Heavy sludge is returned to the river.

Effluent from the pre-sedimentation unit is pumped to the town treatment plant for additional clarification in a second 60-ft. diameter Eimco-Process Reactor-Clarifier. Lime, alum, or activated silica is added to obtain an effluent suitable for sand filtration. Effluent from this 1.5 MGD unit goes to sand filters and chlorination.

Plans and specifications for the treatment plant at Glen Canyon Dam were prepared by engineers of the U.S. Bureau of Reclamation, Denver, Colorado. Richard R. Kennedy, Kennedy Engineers, San Francisco, California, was the consultant. Southern Engineering and Construction Company, Long Beach, California, was the contractor.

Eimco's Process Engineers Division also furnished a 30-ft. diameter Primary Clarifier and a Process RDT Draft Tube Digester-Mixer for the town's 500,000 GPD sewage disposal plant.

For many municipalities, Eimco - Process equipment and cooperative engineering have been the solution to difficult water and wastes treatment problems. The Eimco-Process representative in your area will be glad to help you and your engineers get the most efficient treatment equipment for your requirements.



Eimco-Process Reactor-Clarifiers at Page, Arizona, are located in the pre-treatment plant at the river and in the treatment plant in the town, 700 feet higher

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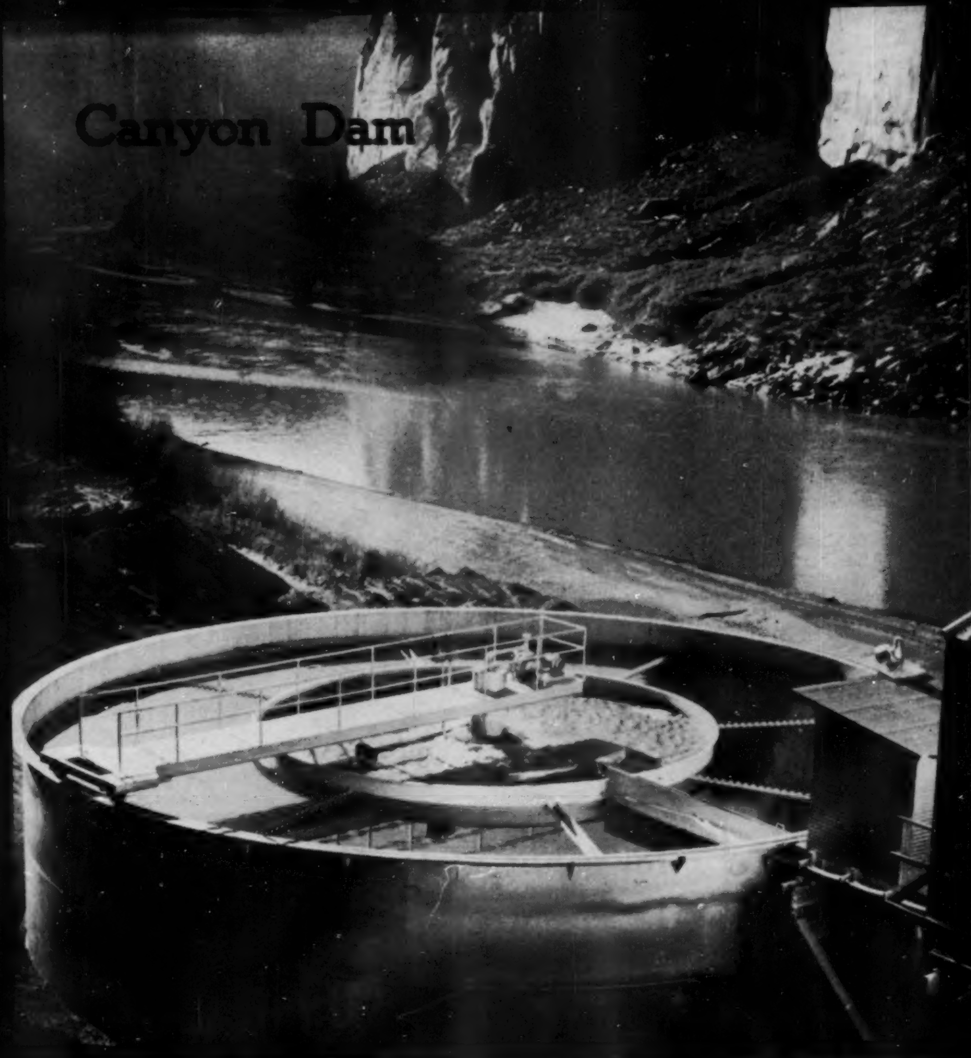
Canyon Dam

(*Continued from page 80 P&R*)

green, and magnesium chloride. Studies have now shown that the inhibitory substance is malachite green, and that magnesium chloride (or certain other divalent cations) is necessary to counteract the toxic effect of the dye on species of *Salmonella* without affecting its inhibitory properties towards Gram-negative contaminants. Only Bacto-Tryptone provided the necessary growth factors in the enrichment medium for the development of *Salm. typhi.* For the enrichment of *Salm. paratyphi*, a Bacto-peptone medium has to be supplemented by Difco-supplements B or C, glutamine, or glutamate.—*WPA*

A Comparison of Media for the Detection of Coliform Organisms in Water. W. H. Jebb. *J. Hyg.*, 57:184 ('59). Five media—MacConkey broth, lactose broth, Teepol broth, lauryl sulfate broth, and glucose glutamic acid medium—were compared as primary media for the isolation of coliform organisms from water. It was found that the total yield of coliform organisms and of *Esch. coli* after incubation for 42 hr was much the same in all the media, but there were large differences in the numbers of false presumptive positive reactions given by the different media. Lactose broth gave the greatest number of false positive reactions, and MacConkey broth the least. It is suggested that further investigations should be made on the use of glutamic acid media, as the glucose glutamic acid medium tested has the advantages of being a chemically defined medium and of not containing any substances which are likely to be inhibitory to coliform organisms.—*WPA*

Growth Characteristics and Antibiotic Production of Actinomycetes Isolated From Littoral Sediments and Materials Suspended in Sea Water. A. Grein & S. P. Meyers. *J. Bacterial.*, 76:457 ('58). Previous work on marine species of actinomycetes is reviewed. Since 1957 work has been in progress to establish the extent to which actinomycetes occur in the

(*Continued on page 86 P&R*)

(*Continued from page 84 P&R*)

sea, the generic nature of this pop. and selected aspects of their physiology, including antibiosis. A number of actinomycete species, including streptomycetes, have been isolated from various littoral sediments. Certain preliminary observations relating to the physiology of these organisms are discussed with special reference to the effects of salinity in the medium and to the antibiotic activity of the organisms. The ecology of these species and their possible identity with terrestrial species are postulated.—*WPA*

CORROSION

Corrosion Problems of Condenser Tubes. J. SULE & E. KRISTYAK. *Energie es Atomtech.* (Hung.), 11:614 ('58). The formation of a corrosion-preventing film on condenser tubes is occasioned by the rate of flow of the cooling water, the contamn. in that water, the construction of the condenser, and the type of material of which the tubes are made. Sr-63-type brass (63^{+2}_{-1}% Cu and 37^{-2}_{+1}% Zn) that is widely used for making condenser tubes in Hungary does not stand up well against corrosion.—*CA*

Corrective Water Treatment Prevents Scale Deposit and Corrosion. J. L. THORNLEY. *Heating, Piping, Air Conditioning,* 31:8:112 ('59). Formation of slime in air washers of water-cooled air-conditioning systems is controlled by the use of Cl, phenolic, or quaternary NH_4 compds. Corrosion of metal is controlled by pH adjustment of the H_2O and the use of phosphates, chromates, or nitrites. Corrosion in chilled-water system is controlled by the use of 500–1000 ppm Na_2CrO_4 and by maintaining pH at 6.8–7.5. In condenser-compressor cooling-water systems, 2–10 ppm polyphosphate and 14–28 ppm silicates are used. For recirculating systems, the usual practice is to hold pH between 6.5 and 7.5 and add inhibitors. These include chromates, phosphates, nitrites, Zn salts, and mixts. of these products. Delignification of wooden cooling towers is prevented by maintaining pH between 6.5 and 7.5, which sometimes requires addn. of H_2SO_4, HCl, citric acid, or $NaHSO_4$.—*CA*

Developments in the Treatment of Circulating Waters—Polyvalent Ion-Polyphosphate Inhibitors. J. I. BREGMAN & T. R. NEWMAN. *Werkstoffe u. Korrosion* (Ger.), 12:309 ('58). Recent investgs. have shown that small addns. of metallic cations to mixtures of polyphosphates and ferrocyanide increase, considerably, the protective effect of these compds. against corrosion. Of the various metals tested zinc proved the most economical. A new product is now commercially available, contg. polyphosphate, ferrocyanide and zinc in the optimum ratio, and has been used successfully in treating condenser cooling water to reduce local attack, and iron and copper concn. in the cooling water and to increase the adherence of the film.—*WPA*

Corrosions Due to Water in the Food Industries. P. H. LEFEBVRE. *Bul. Centre Belge Etude de Document. Eaux,* 36:129 ('57). The various uses of water in the food industry, including the fermentation industry, are listed, and the effects of corrosion are discussed, with reference to the use of water for general purposes, for transport of materials, and in the actual processing of the food. The treatment of the water and precautions to be taken to reduce corrosion are also considered. Corrosion in the

(*Continued on page 88 P&R*)

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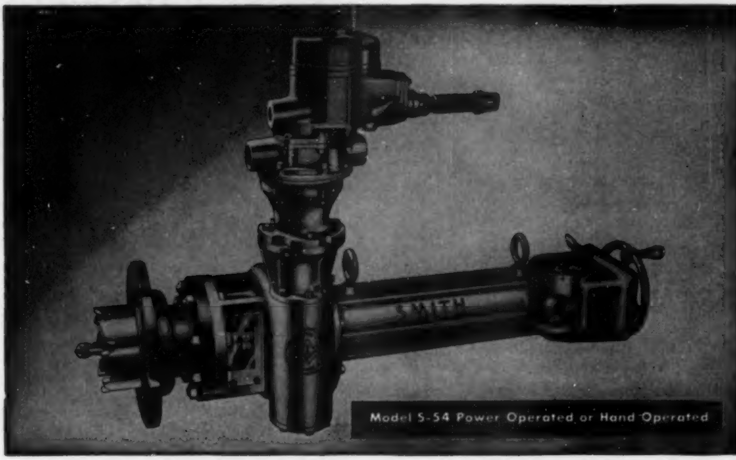

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53

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(*Continued from page 86 P&R*)

food industry is seldom caused directly by the water, but usually by substances in the foods. Descriptions are given of some particular cases of corrosion including corrosion in autoclaves, electrolytic corrosion, and corrosion by brines.—*WPA*

Effects of Mechanics of Flow on Corrosion. A. J. ROMEO; T. SKRINDE; & R. ELIASSEN. *Proc. ASCE, J. San. Eng. Div.*, 84:1702 (Jul. '58). Conflicting corrosion data has shown velocity of fluid flow under many conditions to be inadequate as a corrosion parameter. This paper presents fundamental hydraulic concepts as applied to corrosion and the rate of transfer of interacting chemicals in flow over plates, rotating disks and through pipes.—*PHEA*

OTHER ARTICLES NOTED

Recent articles of interest appearing in periodicals of the water supply field are listed below.

"'Nonstandard' Design and Building Cut Filter Plant Costs $100,000." V. A. VASEEN. *Wtr. Wks. Eng.*, 113:192 (1960).

"How Water Utilities Are Meeting the Impact of Metropolitan Growth." K. H. WALKER. *Wtr. Wks. Eng.*, 113:413 (1960).

"The Design of Small Water Systems." J. A. SALVATO JR. *Public Works*, 91:5:109 (1960).

"Design and Construction of Small Dams." C. A. ELSEA. *Public Works*, 91:6:95 (1960).

"Miami's Master Water Plan." C. F. WERTZ, G. SLOAN & D. B. PRESTON. *Wtr. & Sew. Wks.*, 107:173 (1960).

"Investigation of Liquid Alum Flow Measurement." K. F. KNOWLTON & R. H. BABCOCK. *Wtr. & Sew. Wks.*, 107:189 (1960).

"Pesticides and Lake Rehabilitation." R. O. SYLVESTER & R. H. BOGAN. *Public Works*, 91:7:97 (1960).

"Milwaukee Vapor-Blasts Water Meters." A. RYNDERS. *Am. City*, 75:7:88 (1960).

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James B. Clow & Sons
Dresser Mfg. Div.
Southern Pipe Div. of U.S. Industries
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Aqua Survey & Instrument Co.
Jos. G. Pollard Co., Inc.

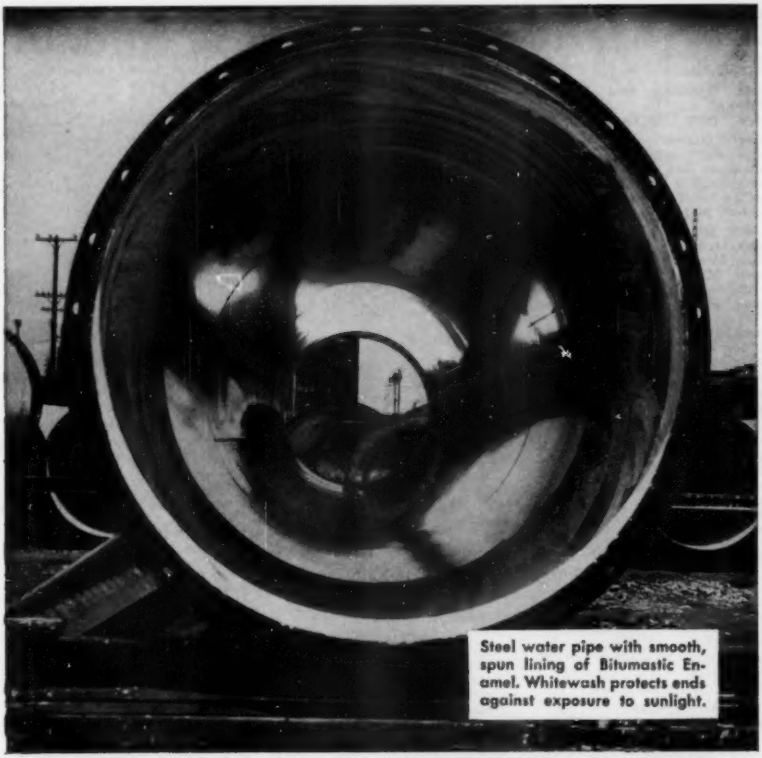
Lime Slakers and Feeders:
B-I-F Industries, Inc.—Omega
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Permutit Co.
Wallace & Tiernan Inc.

Locators, Pipe & Valve Box:
Aqua Survey & Instrument Co.
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Magnetic Dipping Needles:
Aqua Survey & Instrument Co.
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Rockwell Mfg. Co.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.
Ford Meter Box Co.
Gamon Meter Div., Worthington Corp.



Steel water pipe with smooth, spun lining of Bitumastic Enamel. Whitewash protects ends against exposure to sunlight.

FLOW COEFFICIENT=155

The ebony-like finish on the inside surface of the steel water pipe shown above is a typical spun lining of Bitumastic 70-B AWWA Enamel. This type of lining has been tested and proved to have the highest flow coefficient available today.

That's one reason why steel pipe, lined with Bitumastic 70-B AWWA Enamel is such a good investment for water lines. Delivery stays high, too, year after year, since this enamel provides the best protection against tuberculation and incrustation known today.

Investigate steel water pipe—lined and coated with Bitumastic 70-B AWWA Enamel—for your next water-supply project.

Koppers Company, Inc., Tar Products Division, Pittsburgh 19, Pa.

KOPPERS

ONLY KOPPERS MAKES

BITUMASTIC

REG. U. S. PAT. OFF.

70-B ENAMEL

Hays Mfg. Co.
Hersey-Sparling Meter Co.
Mueller Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Simplex Valve & Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Fischer & Porter Co.
Gamon Meter Div., Worthington Corp.
Hersey-Sparling Meter Co.
Neptune Meter Co.
Rockwell Mfg. Co.
Simplex Valve & Meter Co.

Mixing Equipment:
General Filter Co.
F. B. Leopold Co.

Motors, Electric:
Allis-Chalmers Mfg. Co.
Ideal Electric Co.
Marathon Electric Mfg. Corp.
Worthington Corp.

Paints:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
James B. Clow & Sons
Southern Pipe Div. of U.S. Industries
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
American Brass Co.

Pipe, Plastic:
American Hard Rubber Co.
Morgan Steel Products, Inc.
Orangeburg Mfg. Co., Div. of The Flintkote Co.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Morgan Steel Products, Inc.
Southern Pipe Div. of U.S. Industries

Pipe Cleaning Services:
Centriline Corp.
National Water Main Cleaning Co.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
American Hard Rubber Co.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Reilly Tar & Chemical Corp.
Shell Chemical Corp.
Southern Pipe Div. of U.S. Industries

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Pilot Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators; see Locators, Pipe

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Fischer & Porter Co.
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Bailey Meter Co.
B-I-F Industries, Inc.—Builders
Fischer & Porter Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
General Filter Co.
Infilco Inc.
Permutit Co.

Sodium Aluminate:
Nalco Chemical Co.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
Jones Chemicals, Inc.
Wallace & Tiernan Inc.

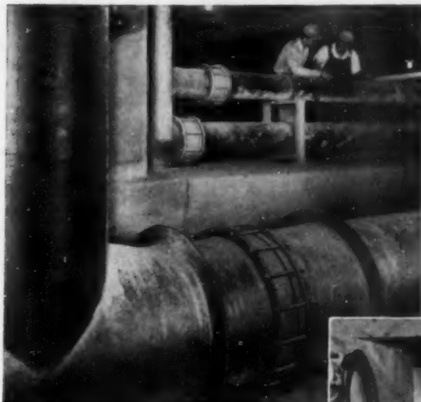
Sodium Silicate:
Philadelphia Quartz Co.

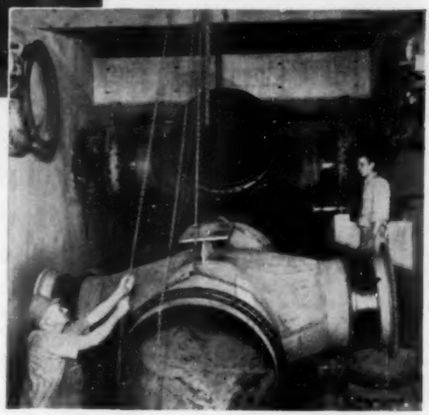
Sodium Silicofluoride:
American Agricultural Chemical Co.
Tennessee Corp.

Softeners:
Dorr-Oliver Inc.
General Filter Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
General Filter Co.
International Salt Co., Inc.
Nalco Chemical Co.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.





Steel Plate Construction:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Ford Meter Box Co.
Hays Mfg. Co.
Mueller Co.

Storage Tanks: see Tanks

Strainers, Suction:
James B. Clow & Sons
R. D. Wood Co.

Surface Wash Equipment:
Golden-Anderson Valve Specialty Co.
Permutit Co.

Swimming Pool Sterilization:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Fischer & Porter Co.
Wallace & Tiernan Inc.

Tank Painting and Repair:
Koppers Co., Inc.
National Tank Maintenance Corp.

Tanks, Prestressed Concrete:
Preload Co., Inc.

Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
General Filter Co.
Industrial Chemical Sales Div.
Permutit Co.
Wallace & Tiernan Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Cc.
Rockwell Mfg. Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey-Sparling Meter Co.

Valves, Electrically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Rockwell Mfg. Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
James B. Clow & Sons
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Large Diameter:
Allis-Chalmers Mfg. Co., Hydraulic Div.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Regulating:
Allis-Chalmers Mfg. Co., Hydraulic Div.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
Rockwell Mfg. Co.
Ross Valve Mfg. Co.

Valves, Swing Check:
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co
M & H Valve & Fittings Co.
Mueller Co.
Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
B-I-F Industries, Inc.—Builders
Rockwell Mfg. Co.
Simplex Valve & Meter Co.

Waterproofing:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
LaMotte Chem. Products Co.
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Well Reconditioning and Formation Testing:
Halliburton Co.
Layne & Bowler, Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite: see Ion Exchange Materials